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AN OPTICAL SYSTEM, AN ANALYSIS SYSTEM AND A MODULAR UNIT FOR AN ELECTRONIC PEN

Field of the Invention

The present invention relates to an optical system, which is arranged to irradiate an object and to transmit an image of the object to an image plane. The invention also relates to an analysis system including such an optical system, and to a modular unit for an electronic pen.

Background Art

In the ever increasing demands on mobility of society of today, it is popular to provide small and portable devices having imaging capability. The optical systems of the above type are thus implemented in handheld devices with imaging capability, such as handheld scanners and electronic pens. In order to restrict the overall sice of such a handheld device including imaging capability, it is accordingly also advantageous to make the included optical system compact.

The optical system typically comprises an irradiating system including a radiation source for providing the irradiation of the object, and an imaging system including a two-dimensional radiation sensor for recording an image of the object. In order for the imaging system to adequately image an object, the entire part of the object viewed by the radiation sensor should preferably be at least essentially uniformly irradiated by means of the radiation source. For handheld devices, the spatial orientation between the optical system and the object, which typically is a plane surface, such as a paper, may vary substantially. For example, during the process of writing with an electronic pen, the pen will frequently be held at varying angles to the paper. Thus,

the spatial orientation of the paper also varies in relation to the radiation sensor and the radiation source. As the angle varies, the relation between the radiation sensor and the writing surface will be changed. This sets demands on an imaging system to adequately image the viewed part of the object for different angles between the pen and the paper.

Further, demands are set on the radiation source to irradiate the object properly. These demands are accentuated when the radiation source and the radiation sensor are arranged at positions that relate to the object in different ways, such as being arranged at different distances to the object and forming different angles to the object. In these cases, the radiation source needs to emit radiation in a large solid angle in order to ensure that the viewed object area is irradiated irrespective of orientation changes between the handheld device and the object.

In WO 03/001358, an electronic pen is disclosed, wherein the problems of providing adequate imaging and irradiating in an electronic pen have been considered. However, the assembly of this electronic pen is not entirely satisfactory. Further, the electronic pen involves relatively long tolerance chains between the components of the radiation sensor and the radiation source, as well as an electrical coupling between the radiation sensor and the printed circuit board that may increase the manufacturing cost, decrease the durability of the pen, and introduce manual assembly steps in the production.

In WO 03/025658, an optical system is disclosed, wherein an optical component is used for enabling the irradiating system and the imaging system to share optical axis. Thus, irrespective of its orientation in relation to the object, the radiation source will irradiate the area of the object being imaged by the radiation sensor.

In US 5,939,702, an optical reader is disclosed, wherein an emitter and a photodiode are mounted on a circuit board and a light pipe is used for communicating light between an external device, such as a paper having optical data, and the emitter and the photodiode. This optical reader forms merely a pointing means and provides no possibility of optical detection while using a writing functionality. The optical reader images only one point at a time and requires scanning for obtaining further data. Moreover, the emitter and the photodiode uses the same light pipe, which may raise problems in the photodiode detecting light that comes directly from the emitter and has not interacted with the external device.

Summary of Invention

It is a general object of the invention to provide an enhanced optical system.

It is a specific object of the invention to provide an optical system that is able to image an irradiated object with increased tolerance to varying orientations and distances between the optical system and the object. It is a further object of the invention to provide an optical system that may be implemented in a more compact size. It is also an object of the invention to at least partly relieve or solve the above-mentioned problems.

These and other objects of the invention that will appear from the following description are fully or at least partly achieved by an optical system according to claim 1, an analysis system according to claim 20, modular units according to claims 21 and 31, a sensor boresight unit according to claim 29, and an optical component according to claim 30. Embodiments of the invention are defined in the dependent claims.

According to one aspect of the invention, it relates to an optical system, which comprises an irradiating system which has an optical axis within said irradiating system and includes a radiation source, and an imaging

system which has an optical axis within said imaging system and includes a two-dimensional radiation sensor, said imaging system being arranged to provide an image of an object being irradiated by said irradiating system, wherein said radiation source and said two-dimensional radiation sensor are mounted on a common substrate, and wherein said optical axis of the irradiating system and said optical axis of the imaging system are non-coinciding within said systems.

The invention provides an optical system, wherein the radiation source and the two-dimensional radiation sensor are arranged in a well-defined spatial relationship to each other, which does not depend on several components. This enables a short tolerance chain for defining the possible variation of the relationship between the irradiated area and imaged area on the object. Thus, the tolerances of the design of components of a device and/or the tolerances of the assembly of the components need not be very harshly set, whereby the yield in serial production may be increased. Alternatively, the required solid angle to be irradiated may be reduced or the variation in orientation allowed in use between a device carrying the optical system and the object may be increased. This is possible, since the variation due to tolerances in the interrelationship between the irradiated area and the imaged area is reduced. Reducing the solid angle implies that the power fed to the radiation source may be reduced, whereby battery lifetime is increased.

The radiation source and the radiation sensor being mounted on a common substrate may be implemented by mounting the radiation source and the radiation sensor on a common printed circuit board. This enables cheap and simple connection of the source and the sensor to electronics for controlling their function and analysing the acquired image information.

An optical axis of a system forms a symmetry line for propagation of radiation in relation to the system. The optical axis extends within and between components of the system, and further extends beyond the components of the system to one or more objects imaged or irradiated by the system. In the context of the present application, the terms "optical axis within the irradiating system" and "optical axis within the imaging system" implies the optical axis as defined only within the components of the respective systems. Thus, these terms do not include the optical axis outside and beyond the components of the respective systems. Further, the definition that the optical axes are "non-coinciding within said systems" implies that the optical axes do not cross each other at any point within the systems.

The provision of non-coinciding optical axes of the irradiating system and the imaging system within the systems provides a possibility to optimize irradiating systems provides a possibility to optimize irradiating optics and imaging optics to their respective purpose. Further, the risk of leakage of radiation directly from the radiation source to the radiation sensor may be reduced.

As mentioned above, depending on the orientation between a device carrying the optical system and the object, different areas of the object will be imaged. At a certain orientation between the device and the object, a planar object may be arranged at the object plane of the imaging system. However, when the orientation is changed, the planar object will not lie in the object plane of the imaging system. The imaging system may still image the planar object by a depth of field of the imaging system allowing deviations from the object plane.

The irradiating system may be arranged to redirect radiation from the radiation source, and the imaging system may be arranged to redirect radiation from the irradiated object towards the radiation sensor. This implies that the radiation source and the radiation

sensor may be arranged on a substrate that extends in a direction substantially along a longitudinal axis of an elongate device, wherein the area to be imaged and irradiated is at a short end of the device. If the optical system is implemented in a handheld device, such as an electronic pen, the device mainly extends in this direction. Thus, this arrangement is suitable if the radiation source and the radiation sensor are to be mounted on e.g. a common printed circuit board in an electronic pen.

The optical axis within the irradiating system and the optical axis within the imaging system may run essentially in parallel to each other. This ensures that the optical axes will be non-coinciding within the systems. Further, optical components of the irradiating system and optical components of the imaging system may be arranged without interfering with each other.

The optical axis within the irradiating system and the optical axis within the imaging system may further run essentially parallel to the common substrate. Thus, the substrate will not interfere with the optical path of the irradiating and imaging systems.

Moreover, the optical axis within the irradiating system and the optical axis within the imaging system may define a plane which is essentially parallel to and at a distance from the common substrate. This implies that the optical axes of the irradiating system and the imaging system are arranged side by side over the common substrate. Thus, the height of the irradiating system and the imaging system over the common substrate may be minimized, since they need not be arranged on top of each other. As a result, the diameter of an electronic pen including the optical system is kept small.

The irradiating system may further comprise a radiation guide for guiding radiation from the radiation source towards the object. The radiation guide may guide the direction of emitted radiation from the radiation

source in order to direct it correctly towards the object. Further, there is a control of the emitted radiation, reducing the spreading of stray radiation. The radiation guide may comprise a mirror above the common substrate over the radiation source to provide the redirection of radiation from the radiation source.

The radiation guide may present non-exit surfaces at least part of which may be metallized. Thus, surfaces of the radiation guide not intended for output of radiation are metallized to prevent leakage of radiation. This further enhances control of stray radiation from the radiation source and enhances control of the distribution of the emitted radiation.

It should be noted that, as used herein, "stray radiation" implies either radiation that does not give the radiation sensor information on the imaged area, since it may not be related to an origin in this area, or radiation which has passed or leaked directly from the radiation source to the radiation detector without having interacted with the object to be imaged.

Further, the radiation guide may present an inclined radiation-redirecting exit surface. This implies that a normal axis of the exit surface is inclined to the optical axis within the irradiating system. This provides a redirection of the radiation emitted from the radiation source towards the object. Thus, the exit surface may be inclined so as to direct the emitted radiation to create an irradiated area that better corresponds to an imaged area at the object.

The radiation guide may also be mounted on the common substrate. This distinctly defines the position of the radiation guide of the irradiating system in relation to the radiation source, whereby the tolerance chain of the irradiating system is kept short. The tolerance of the irradiating system defines a deviation from a nominal position of the irradiated area on the object. Thus, keeping the tolerance chain short implies that a better

control is obtained for the set position of the irradiated area on the object.

The imaging system may further include a sensor boresight unit for controlling a spatial origin of radiation transmitted towards the radiation sensor. The sensor boresight unit thus controls the area viewed by the sensor. It will therefore define the boresight of the sensor. The sensor boresight unit of the imaging system is preferably a separate unit from the radiation guide of the irradiation system. The sensor boresight unit also provides control of stray radiation, preventing it from being detected by the radiation sensor.

The sensor boresight unit may also be attached to the common substrate. This defines the position of the sensor boresight unit of the imaging system in relation to the radiation sensor, whereby the tolerance chain of the imaging system is also kept short. The tolerance of the imaging system defines a deviation from a nominal position of the imaged area on the object. Thus, keeping the tolerance chain short implies that a better control is obtained for the set position of the imaged area on the object.

Further, where the sensor boresight unit and the radiation guide are both mounted on the common substrate, the spatial interrelationship of these parts may also be well-defined, whereby a short tolerance chain is obtained for the relationship between the imaging and the irradiating systems. This implies that the interrelationship between the imaged and irradiated areas on the object may be adequately controlled.

The sensor boresight unit may comprise a mirror for redirecting radiation from the object towards the radiation sensor. The mirror is suitably arranged over the substrate on which the radiation sensor is mounted and above the radiation sensor to reflect radiation from the object directly onto the radiation sensor.

The sensor boresight unit may further comprise a lens for creating an image of adequate image quality on an image plane of the radiation sensor. The lens provides focus of the object plane onto the radiation sensor. The depth of field of the imaging system is suitably arranged to view an object placed in or near the object plane such that a sufficient image quality may be obtained for allowed changes to the optical set-up causing the object to move away from the object plane.

The sensor boresight unit may comprise an optical component, which is arranged to transmit radiation towards the radiation sensor, wherein the optical component comprises a mirror for redirecting radiation from the object towards the radiation sensor, and a lens for creating an image of adequate image quality on an image plane of the radiation sensor. In this way, the sensor boresight unit comprises few components, whereby tolerance chains of the production of the optical system are shortened. Especially, no account need be taken to tolerances due to assembly of these components. This implies that the allowed variation in the interrelationship between the irradiated area and the imaged area due to tolerances in components is reduced. As mentioned above, reduced tolerance chains imply that the irradiated area may be reduced and, thus, that the power fed to the radiation source may be reduced. This also gives less problems with stray radiation since the emitted power is reduced.

The sensor boresight unit may further comprise an aperture stop, which is arranged in front of the optical component. The aperture stop provides blocking of radiation that will not be directly transmitted to the image plane by the optical component. This reduces influence by radiation not holding information on the imaged area. The aperture stop may be used for adjusting the depth of field of the imaging system. Decreasing the

size of an opening of the aperture stop will increase the depth of field of the imaging system.

The optical component presents outer surfaces at least part of which may be covered with a material arranged to reduce internal reflections in said outer surfaces. The cover material may have optical properties adapted to provide that the majority of radiation impinging the cover material from the inside of the optical component will not be reflected back into the optical component. Thus, the cover material may have a refraction index that is matched to the refraction index of the material of the optical component, whereby radiation incident on the cover material will be transmitted into the cover material. Additionally or alternatively, the cover material may provide absorption of radiation that impinges the walls from the inside of the component. This reduces stray radiation caused by internal reflections or scattering in the optical component. The cover material has suitably a large absorption coefficient for radiation wavelengths acquired by the sensor. Further, the cover material may also be selected to prevent radiation from entering the optical component through the cover material. For instance, this may be achieved by the cover material absorbing or reflecting the radiation impinging it from outside the optical component. This would provide an effective block for radiation incident upon the optical component through other surfaces than an entrance surface.

The optical component may be implemented as a solid optics component formed by a unitary body. The solid optics component may be formed of a plastic material, such as polymethylmethacrylate (PMMA), polycarbonate (PC), Zeonex®, polystyrene, nylon, or polysulfone.

The sensor boresight unit may alternatively comprise a housing, providing an internal channel, which is arranged to transmit radiation towards the radiation sensor, wherein a mirror for redirecting radiation from

the object towards the radiation sensor and a lens for creating an image of adequate image quality on an image plane of the radiation sensor are mounted in the housing. This implementation of the lens and the mirror implies that the imaging optics is constituted of separate conventional components, whereby manufacture and quality control is easily implemented. Further, the housing may be structured to be suited for attachment to the common substrate.

The sensor boresight unit may further comprise an aperture stop arranged in the housing. The aperture stop may be formed as a part of inside surfaces of the housing. In this way, the housing may hold all components of the imaging system controlling the radiation path towards the radiation sensor.

The housing presents inside surfaces at least part of which may be arranged to reduce specular reflection of radiation. The inside surfaces may comprise a material which absorbs radiation, and specifically absorbs radiation wavelengths that are acquired by the sensor. The inside surfaces of the housing may also or alternatively be rough or have an appropriate texture in order to avoid specular reflections. This reduces stray radiation to the radiation sensor caused by internal reflections or scattering in the housing.

According to another aspect of the invention, it relates to an analysis system, which comprises an optical system according to the invention, a printed circuit board implementing said common substrate, and an image processor for analysing image information received from the radiation sensor, wherein the optical system is supported by and the image processor is mounted on the printed circuit board.

The optical system being supported by the printed circuit board implies that the spatial positions of the components of the optical system are defined by their relation to the printed circuit board, even though each

component does not need to actually be mounted on or attached to the printed circuit board. For example, a sensor boresight unit of the optical system need not be attached to the printed circuit board. However, the radiation sensor and the radiation detector of the optical system should be mounted on the printed circuit board. The arrangement of the optical system being supported on a printed circuit board provides a well-defined spatial interrelationship of components of the optical system. Thus, a compact arrangement for the acquiring of images and the processing of the images is provided. Further, the analysis system readily provides control of the radiation source, which is mounted on the printed circuit board, and further provides simple and cheap connection of the radiation sensor to an image processor.

According to a further aspect of the invention, it relates to a modular unit for an electronic pen having a writing means, said modular unit comprising a carrier, and an analysis system according to the invention being mounted on the carrier, said carrier having means for receiving said writing means in order to position the writing means in relation to the analysis system within the electronic pen.

This arrangement of a modular unit provides a possibility to test the quality of the analysis system before the electronic pen is finally mounted inserting the modular unit into an outer shell of the electronic pen. Thus, defects in the analysis system may be detected at an earlier stage in the production, whereby fewer steps need be made for defective products. This speeds up and improves the production process.

Since the analysis system is mounted on the carrier and the carrier provides a means for receiving a writing means, the spatial relationship between the analysis system and the writing means is defined by the design of the carrier. This implies that the imaged area and the

irradiated area are accurately defined in relation to a pen point of the writing means in contact with the object. Further, the mutual mounting on the carrier of the analysis system and the writing means implies that the modular unit provides a short tolerance chain of the relation of the imaged and irradiated areas to the pen point.

The term "modular unit" should be construed as a unit that may be assembled and which is not held together by pieces that do not form part of the unit. In this case, the modular unit for the electronic pen forms an integral unit before final assembly of the electronic pen.

The modular unit suitably has a dimension allowing the modular unit to be mounted inside the electronic pen. Thus, in the assembly of the electronic pen, the modular unit may in its entirety be mounted within the electronic pen.

The printed circuit board of the analysis system may be mounted on the carrier for mounting the analysis system on the carrier. Thus, the position of the printed circuit board may be fixed by the carrier. This implies that the insertion of the modular unit into the outer shell of a pen need not comprise securing the position of the printed circuit board in the shell.

The carrier may have an elongate shape which extends, when the modular unit is comprised in an electronic pen, in a longitudinal direction of the electronic pen. Hereby, the carrier may provide possibility to fix the position of several components of the pen along the longitudinal shape of the pen.

The modular unit may further comprise a pressure sensor which is mounted on the carrier. The pressure sensor may detect when the writing means is pressed against a writing surface. This detection may activate the optical system to irradiate and image the writing surface, which forms the object. The pressure sensor's

functionality may be obtained by components arranged integrated on the carrier or may, alternatively, be obtained by a pressure sensor unit that is mounted on the carrier.

The modular unit may also comprise means for forming attachment to an outer shell part of the electronic pen. Thus, the modular unit is prepared for installation in the pen shell. The means for forming attachment could be a hook or pin for engaging the outer shell part or a slot or recess for receiving a protrusion from the outer shell part.

Further, the modular unit may comprise a vibrator unit, which is mounted in the carrier. The vibrator unit may by vibration provide feedback to the user e.g. when the electronic pen fails to appropriately image the writing surface.

Moreover, the modular unit may comprise a wavelength filter mounted on the carrier. The wavelength filter may be arranged such that the radiation from the object passes the wavelength filter before being detected by the radiation sensor. Thus, undesired wavelengths for the analysis to be performed by the analysis system may be filtered out.

According to a still further aspect of the invention, it relates to a modular unit for an electronic pen having a writing means, said modular unit comprising a carrier; a printed circuit board, which is mounted on the carrier; and an optical system, which is mounted on the carrier, said optical system comprising an irradiating system including a radiation source and an imaging system including a two-dimensional radiation sensor, the imaging system being arranged to provide an image of an object irradiated by said irradiating system; wherein said carrier has means for receiving said writing means in order to position the writing means in relation to the optical system within the electronic pen.

According to this aspect of the invention, there is provided a well-defined spatial relationship between the optical system and a writing means of the electronic pen, since the optical system is mounted on the carrier and the carrier provides a means for receiving a writing means. The design of the carrier defines this spatial relationship.

According to an embodiment of this modular unit, the imaging system comprises a sensor boresight unit for controlling a spatial origin of radiation transmitted towards the radiation sensor.

The sensor boresight unit may be supported by the printed circuit board. Thus, the printed circuit board may define the position of the sensor boresight unit. However, the sensor boresight unit need not be actually mounted or attached to the printed circuit board. The sensor boresight unit may, for example, be attached directly to the carrier while being supported by the printed circuit board. Since the printed circuit board defines the position of the sensor boresight unit, a short tolerance chain of the spatial relation between the sensor boresight unit and the radiation sensor is obtained.

The radiation source of the irradiating system may be carried by the sensor boresight unit of the imaging system. This provides that the radiation source is kept in a close relationship to the imaging system, whereby the effects of the pen orientation on the interrelationship between the imaged and irradiated areas on the writing surface is minimized. The radiation source may, for example, be arranged in a holder that is attached to the outside of the sensor boresight unit.

According to still another aspect of the invention, it relates to a sensor boresight unit for transmitting radiation from an object to a radiation sensor, said sensor boresight unit comprising a housing, which provides an internal channel that changes direction at a

turn within said housing and further provides a radiation entrance end and a radiation exit end of said channel, a lens, which is mounted in the internal channel at said radiation entrance end of said housing, and a mirror, which is mounted in the housing at said turn of the internal channel for redirecting radiation along the change of direction of the internal channel.

According to yet another aspect of the invention, it relates to an optical component for transmitting radiation from an object to a radiation sensor, said optical component being formed by a solid body defining a radiation path within the body, said solid body comprising a radiation entrance surface for receiving radiation into said radiation path, said entrance surface being curved for forming a lens, a radiation exit surface, a tubular part for transmitting radiation in the radiation path along a longitudinal axis of the tubular part, and a mirror surface at an end of the tubular part opposite the entrance surface, wherein a normal of the mirror surface is slanted to the longitudinal axis of the tubular part such that the radiation path is redirected in the mirror surface towards the radiation exit surface of the solid body.

Both these last-mentioned aspects of the invention respectively provide devices for transmitting of radiation from an object to a radiation sensor. This transmitting of radiation may advantageously be used in an imaging system for collecting radiation from the object and redirecting the radiation towards a radiation sensor. Thus, these devices respectively enable positioning of the radiation sensor more freely in relation to the object to be imaged by the radiation sensor.

Brief Description of the Drawings

The invention will now be described in further detail with reference to the accompanying schematic

drawings, which by way of example only illustrate presently preferred embodiments of the invention.

Figs 1a and 1b illustrate angles defining an orientation of an electronic pen in relation to a writing surface.

Fig. 2 illustrates relations between contact point, imaged area and irradiated area for an optical system of the electronic pen.

Fig. 3 is a side view of the electronic pen.

Fig. 4 is a perspective view of a modular unit in an electronic pen, where the outer shell of the pen has been removed.

Fig. 5 is a perspective view of components of a modular unit for the electronic pen before being assembled.

Fig. 6 is a perspective view of the components of the modular unit of Fig. 5 after being assembled.

Fig. 7 is a side view of an ink cartridge and illustrates the effect of a radial gap between the ink cartridge and a receiving bore of the pen.

Fig. 8 is a perspective view of an analysis system comprising an optical system and a processor.

Fig. 9 is a side view of an imaging system of the optical system.

Fig. 10 is a sectional view of an embodiment of the imaging system.

Fig. 11 is a sectional view of another embodiment of the imaging system.

Fig. 12 is a side view of an embodiment of an irradiating system of the optical system.

Detailed Description of Embodiments of the Invention

Referring now to Figs 1-4, the parts and components of an electronic pen and the functionality of the pen will initially be summarily described. Although the invention is not restricted to its use in an electronic pen, an embodiment of the invention as used in an

electronic pen will illustrate the features and functionality that may be obtained by the invention according to at least some aspects.

The basic properties of an electronic pen 1 will initially be described. In Figs 1a-b, an ink cartridge 8 of an electronic pen 1 is shown. The ink cartridge 8 comprises a pen point 9, which will contact a writing surface 14, when a user is writing. The writing surface 14 comprises a pattern, which carries information on the writing surface 14. The pattern may encode a position on the writing surface 14 or general information regarding what the writing pertains to. This may be used for calculating the movement of the pen point 9 and/or for registering if writing is made in a special area on a paper, such as a check box or a date in a calendar. In order to decode the pattern on the writing surface, the pen 1 comprises an imaging system 15 (Fig. 4) for imaging an area on the writing surface 14. Using the imaged area, the pen 1 may determine the position of the pen point 9 on the writing surface 14. The imaging system 15 comprises a focussing lens for obtaining a sufficiently sharp image of the imaged area. Further, in order for the imaging system 15 to adequately image the area on the writing surface 14, this area should be irradiated by a radiation source.

When a user writes, the orientation of the ink cartridge 8 in relation to the writing surface 14 will vary. Ideally, an area centred around the pen point 9 should be imaged, to minimize any variations in the relation between the imaged area and the pen point 9 resulting from the varying pen orientation. However, this is difficult to achieve, since the optical axis of the imaging system 15 would then have to be placed coinciding with the longitudinal axis of the ink cartridge 8. Further, the ink cartridge 8 and the pen point 9 may then obscure the imaged area. Thus, the imaging system 15 is arranged to image an area adjacent to the pen point 9.

This implies that the relation between the imaged area and the pen point 9 will depend on the orientation between the ink cartridge 8 and the writing surface 14, as will be explained below.

In Figs 1a-b, the orientation between the ink cartridge 8 and the writing surface 14 is illustrated. This orientation may be described by using three angles. As shown in Fig. 1a, the ink cartridge 8 forms an inclination angle θ, which is defined as the tilt angle between the ink cartridge 8 and the normal of the writing surface 14. The inclination angle θ may vary substantially during writing. Further, as shown in Fig. 1a, the pen 1 may be rotated around the longitudinal axis of the ink cartridge 8. Since the imaging system 15 is not arranged on this axis, such a rotation will affect the relation between an imaged area and the pen point 9. The rotation of the pen 1 around the longitudinal axis of the ink cartridge 8 is called a skew angle φ. Moreover, as shown in Fig. 1b, the pen 1 may be rotated in relation to the pattern on the writing surface 14. This rotation around the normal of the writing surface 14 is called a pattern rotation angle α.

Referring now to Fig. 2, the effects of differing inclination angle θ between the ink cartridge 8 and the writing surface 14 is illustrated. Three different writing surfaces WS_0, WS_{-45}, WS_{45} are shown to illustrate differin**Fel! Objekt kan inte skapas genom redigering av fältkoder.** inclination angles, namely $\theta=0°$, $\theta=-45°$, and $\theta=45°$, respectively, between the ink cartridge 8 and the writing surface 14. As shown in Fig. 2, the writing surface 14 is arranged at different positions along an optical axis C of the imaging system depending on the inclination angle θ. Thus, the distance between a radiation sensor of the imaging system 15 (Fig. 4) and the imaged area on the writing surface 14 will also depend on the inclination angle θ. The inclination angles θ that are allowed during writing define a range of

distances between the imaged area and the radiation sensor, at which the radiation sensor should detect the imaged area with an adequate sharpness over relevant parts of the imaged area for decoding the pattern on the writing surface 14. This range of distances is called the depth of field requirement FD of the imaging system 15. As seen in Fig. 2, this necessary depth of field FD is proportional to the distance D in a reference plane, which in this case is the plane of the writing surface at inclination angle $\theta=0$, between the contact point P, i.e. the pen point 9, and the optical axis C of the imaging system 15. In order to provide a large depth of field, the imaging system 15 should have a low f-number, whereby low amounts of radiation are passed to the radiation sensor. For this reason, it is desired that this optical axis offset or distance D is designed as small as possible for the arrangement of the imaging system 15 in the pen 1.

The imaging system 15 images an area on the writing surface 14, which is the field of view of the imaging system 15. Since the magnification of an object onto an image plane in the radiation sensor is inversely proportional to the distance between the object and the lens of the imaging system 15, the magnification of the field of view will increase with increasing inclination angle θ between the ink cartridge 8 and the writing surface 14. The field of view that is imaged onto an active area on the radiation sensor is smaller at a larger magnification. The imaging system 15 should image an area on the writing surface 14 which holds sufficient amounts of information for decoding a pattern on the writing surface 14. The field of view should therefore be large enough to allow imaging of a decoding area DA. Thus, an upper limit of the magnification is set in order for the field of view to include a decoding area DA. Further, a lower limit of the magnification is set in order to enable discrimination of the smallest details of

the pattern. Also, by keeping the necessary depth of field FD as small as possible, the variation in the magnification of the imaged area is minimized.

However, to keep the necessary depth of field FD as small as possible, the field of view should be arranged next to the tip of the ink cartridge 8. Thus, there is a risk that the field of view becomes partly obscured by the tip of the ink cartridge 8. If the ink cartridge 8 obscures a large part of the field of view, the imaged area of the writing surface 14 may not be large enough to enable decoding of the pattern. This implies that the distance D should not be designed too small. If an angle between the optical axis C and the longitudinal axis A of the ink cartridge 8 is increased while keeping the distance D constant, the obscuration of the tip of the ink cartridge 8 in the field of view may be reduced. However, a greater angle also implies that the optical axis C is further apart from the longitudinal axis of the ink cartridge 8 inside the pen 1, resulting in a larger radius of the pen 1.

As briefly mentioned above, at least the relevant parts of the imaged area, i.e. the decoding area DA holding the pattern to be decoded, should be irradiated. This may easily be ensured, if an optical axis I of an irradiating system 13 is arranged coincident with the optical axis C of the imaging system 15. However, if the optical axes C, I of the imaging and irradiating systems 15, 13 are arranged to coincide, optical components on the coinciding optical axes need to be adapted to perform functions of both the imaging and irradiating systems 15, 13. This may result in loss of radiation in the optical components. On the other hand, if the optical axes C, I are arranged not to coincide, the relation between the imaged area and the irradiated area will depend on the angles between the ink cartridge 8 and the writing surface 14. Then, the design of the pen needs to arrange the irradiating system 13 such that the irradiated area

always includes the relevant parts of the imaged area for all allowed angles between the ink cartridge 8 and the writing surface 14. The irradiating system 13 should irradiate the decoding area DA properly, for example with sufficiently uniform radiation of a sufficient magnitude (irradiance). The uniformity may be defined by the largest difference in irradiance and/or the irradiance gradients within the decoding area DA.

The accumulated decoding areas DA for all allowed angles between the ink cartridge 8 and the writing surface 14 define a space that is to be irradiated. As illustrated above, this space depends on the design of the pen 1, i.e. on the distance D, the decoding area DA, the angle between the optical axis C and the longitudinal axis of the ink cartridge 8 and the allowed angles between the ink cartridge 8 and the writing surface 14. Thus, the irradiating system 13 should be arranged to emit radiation in such a large solid angle γ that it covers the space to be irradiated. Placing the optical axis I of the irradiating system 13 close to the optical axis C of the imaging system 15 implies that the required solid angle γ is kept relatively small. The properties of the irradiating system 13 needed for obtaining the required solid angle γ could be designed by calculating the irradiation pattern using a ray-tracing program.

Above, the effects of differing inclination angles θ have been explained. Further, differing skew angles affect the requirements on depth of field FD and the irradiated space. Again, increasing the distance D implies that a larger depth of field FD and a greater irradiated space are needed when varying skew angles are allowed.

When the pattern rotation angle α is changed, the encoded pattern viewed by the imaging system 15 will be changed. This needs to be accounted for in calculation of the position of the pen point 9 on the writing surface 14. Where the needed information for decoding the encoded

pattern is defined by a square, allowing all pattern rotation angles α implies that the required size of the imaged area of the writing surface is defined by a circle formed by rotating the square pattern. However, varying the pattern rotation angle α will not affect the size of the area being imaged, the distance of the imaged area to the radiation sensor or the distance D.

The pen 1 is designed with nominal parameters, such as sizes and relative mounting angles and distances, on all components of the pen 1. This design gives a nominal value of the distance D. However, in manufacturing the pen 1 tolerances to the nominal parameters should be allowed. Tolerance chains add up to set requirements on allowed largest value of the distance D. This largest value sets the requirement on the depth of field FD of the imaging system 15. Further, tolerance chains add up to define possible needed irradiated spaces.

In designing the pen 1, the above-explained parameters of the imaging and irradiating systems 15, 13 should be considered. If the nominal distance D between the pen point 9 and the optical axis C of the imaging system 15 in the reference plane is decreased, the nominal depth of field FD may be reduced. This implies that an opening of an aperture stop in the imaging system 15 may be increased allowing more radiation to reach the radiation sensor. Thus, the power of the radiation source may be reduced, whereby battery lifetime of the pen 1 is increased. The decreased distance D may alternatively be used to allow the pattern on the writing surface 14 to comprise smaller details, while the imaging system 15 is unchanged. The decrease in the nominal distance D may as a further alternative be used for allowing larger differences in the angles between the ink cartridge 8 and the writing surface 14, while keeping the nominal depth of field FD constant. Further, the decrease in the nominal distance D may be used for allowing larger

tolerances in individual components of the pen 1 or in the assembly of the components.

These parameters, i.e. the nominal distance D, the nominal depth of field FD, the scale of the details on the writing surface 14, the allowed variation in the angles between the ink cartridge 8 and the writing surface 14, and the allowed tolerances may be varied in several different ways, wherein an increased requirement of one parameter may cause increased requirements of one or more of the other parameters.

With insufficient control of the tolerance chains, the distance D may thus for some pens be so great that the imaging system 15 is not capable of supplying useful images to the processor 16 (Fig. 4). This may be solved by constructing the imaging system 15 with a great nominal depth of field by decreasing the opening of an aperture stop and/or decreasing the focal length of an imaging lens. This, however, may cause an undesirable restriction on the amount of radiation that can be transferred to the radiation sensor.

As is apparent from the above, the imaging and irradiating systems 15, 13 in a pen 1 have some parameters that are closely related and set different requirements to the systems. When designing the systems, the choice of a parameter implies that all other parameters are affected as described above. Thus, the design should be accurately and carefully developed in order to meet the requirements.

The presently preferred embodiments are designed to handle decoding areas DA of approximately 3-5 mm. The distance D is suitably set in the range of about 2-4 mm, and the necessary depth of field is suitably set in the range of about 2.5-10 mm, preferably in the range of about 4-8 mm, and most preferably in the range of about 6.5-7.5 mm. Preferably, the optical system is designed to allow for a symmetric range of inclination angles θ, for all skew angles φ, so as to allow the user to grip and

write with the pen at any skew angle. Preferably, the range of allowable inclination angles comprises about ±30°, and preferably about ±40°. Preferably, the imaging system is designed with a length of the optical axis C, from the writing surface to the radiation sensor at $\theta=0°$ and $\varphi=0°$, in the range of about 15-60 mm, preferably about 30-45 mm. At the lower limit, the imaging system may require an undesirably small aperture stop and exhibit significant image distortion. At the upper limit, the imaging system may take up significant longitudinal and radial space in the pen and/or require an optically redirecting element at the front end of the pen.

Below, some embodiments of imaging and irradiating systems within a pen 1 will be described, further illustrating ways of designing the pen 1 to at least satisfactorily meet the above-mentioned requirements.

The pen 1 in Fig. 3 has a body 2 with a forward portion 2a and a cap 3 with a clip 4. A carrier 5 is arranged mainly inside a casing 6 of the pen 1, as illustrated in Fig. 4. The carrier 5 constitutes part of the interior of the pen 1 and extends in the longitudinal direction of the pen 1 towards a rear portion 7 of the pen 1. An ink cartridge 8 with a pen point 9 is inserted into a receiver 10 in the carrier 5, as illustrated in Figs 5-6. The receiver 10 provides a through bore 10a in the forward part 2a of the pen 1 and an extension of the through bore 10a into a longitudinal groove 10b. The ink cartridge 8 is slid into the receiver 10 and may be replaced by a user. Between the ink cartridge 8 and the receiver 10 there is a certain radial play. An optical system 11 is attached to a printed circuit board 12, which is mounted on the carrier 5. The optical system 11 comprises an irradiating system 13 for emitting and directing emitted radiation towards an object, which is typically a writing surface 14, such as a paper, on which the user writes using the pen 1. The optical system 11 further comprises an imaging system 15 for collecting and

detecting radiation from the object in order to record images of the object. The recorded images are transferred to an image processor in the form of a processor 16 on a printed circuit board 12 and analysed therein.

The pen 1 comprises a means for providing power to the processor 16, the optical system 11 and any other parts of the pen 1 that need electric power. The means for providing power may be a battery 21 or a flexible cord (not shown) for connection to an external source of power. The pen 1 may further comprise a means (not shown) for enabling connection to an external computer unit for transfer of recorded images or information from the processor 16. The means for enabling connection to an external computer unit may be a wireless transmitter/receiver, a cradle connector or any kind of wire connection, such as a USB-connector.

When the pen 1 is not used, the cap 3 is normally arranged on the forward portion 2a of the pen 1 and then protects the pen point 9 and other components in the forward portion 2a of the pen 1. The clip 4 can then be used to fix the pen 1, for instance, in a shirt pocket. When the pen 1 is to be used, the cap 3 is removed and the pen 1 is set in a standby mode, wherein the pen 1 is sensible for actions that should activate the pen 1.

The pen 1 further comprises a pressure sensor arrangement 17, which is mounted in a pressure sensor receiving pocket 18 on the carrier. The pressure sensor arrangement 17 is installed at the end of the groove 10b of the receiver 10. The pressure sensor arrangement 17 receives a rear end of the ink cartridge 8, when inserted into the receiver 10. When the pen point 9 is pressed against a writing surface 14, the ink cartridge 8 will be pressed towards a pressure sensor 19 attached to a wall of the pocket 18. The pressure sensor 19 will sense the exerted pressure. The sensing of a sufficient pressure by means of the pressure sensor 19 is used to fully activate the controlling electronics, such as the processor 16,

and thereby also activating the irradiating system 13, the imaging system 15, etc. Further, the amount of pressure may be determined and associated to the corresponding image recorded at the same time. The amount of pressure may then be used for illustrating the thickness of the strokes drawn with the pen 1.

In the embodiment of Figs 5-6, the rear end portion of the ink cartridge 8 is inserted and press fitted into an insert 22, which is movably arranged in the pressure sensor receiving pocket 18. The pressure sensor 19 is attached to a wall in the space defined by the pocket 18. The space is defined so that the insert 22 can move towards and away from the pressure sensor 19, but simultaneously so that the insert 22 cannot move out of the pocket 18. The insert 22 is designed in such manner that it can hold various makes of similar ink cartridges, which makes it possible to use exchangeable ink cartridges for ordinary ball point pens. The insert 22 ensures good contact with the pressure sensor 19 when the pen point 9 of the ink cartridge 8 is pressed against the writing surface 14 and reduces the risk of ink possibly leaking out damaging the pressure sensor 19. The design of the pocket 18 causes the insert 22 to stay in the right place when an ink cartridge 8 is removed from the pen 1 to be exchanged. The radial play between the ink cartridge 8 and the receiver 10 ensures that the ink cartridge 8 can be removed from the pen 1 with minor resistance only. When mounting a new ink cartridge 8, the receiver 10 ensures that the ink cartridge 8 is correctly positioned in the interior of the pen 1.

It is conceivable to essentially eliminate the radial play between the cartridge 8 and the receiver 10, in order to tighten the relationship between the pen point 9 and the imaging system 15. However, since the pen point 9 generally has a non-zero radial extension, the part of the pen point 9 being in actual contact with the writing surface 14 will vary with the inclination angle

and the skew angle of the pen 1. This causes an inaccuracy in the determination of the pen point location on the writing surface 14. A ballpoint pen typically has a pen point (roller ball) with a diameter of about 0.5 mm. For inclination angles of ±45°, the above inaccuracy is about 0.35 mm, which is large enough to be visible if the handwriting is reproduced against a ruled background that represents the writing surface. It is possible to calculate a compensation value to minimize this inaccuracy, if the geometry of the pen point 9 is known, as well as the instant inclination and skew angles. However, it has been found that these inaccuracies instead can be lowered by careful design of the total radial play. Fig. 7 shows the ink cartridge 8 at two extreme inclinations: +45° (solid lines) and -45° (dashed lines). As can be seen, the actual contact point remains essentially constant. This may be achieved by the size of a radial gap RG being set equal to the effective diameter of the area that is defined by the location of the contact point on the pen point 9, at the extreme pen inclination angles for a zero radial play embodiment, as projected onto a plane perpendicular to the longitudinal axis of the ink cartridge 8. In practice, the radial gap RG is set to about 40-90% of the effective diameter, to take into account that the pen point 9 generally sinks into the writing surface 14 during writing.

The mounting of the pressure sensor arrangement 17 in the pocket 18 (Figs 4-5), which has a well-defined position on the carrier 5, minimises risk of misalignment of the ink cartridge 8 and the pressure sensor arrangement 17. Such misalignment may interfere with the axial motion of the ink cartridge 8, so that an arbitrary delay is introduced in the pressure sensor's detection of the pen's contact with the writing surface. Furthermore, such misalignment may cause wear on the insert 22 and/or the pressure sensor 19. The mounting of the pressure

sensor arrangement 17 on the carrier 5 may also reduce the pen's susceptibility to mechanical shocks.

The carrier 5 may also be effective in protecting the electronic circuits of the pen against electrostatic discharge (ESD), in the form of overvoltage discharges or sparks over small insulating gaps, e.g. air gaps, between conductive members in the pen 1. ESD may cause serious damage to the electronic circuits and/or latchup thereof. The problem of ESD may be enhanced in electronic pens, since electrical charge may travel into or out of the pen 1 via the ink cartridge 8, which is often made of metal. In the embodiment of Figs 4-6, all such small gaps between the cartridge/pressure sensor and the PCB are effectively eliminated by the receiver 10 and the pocket 18 being located on one side of carrier 5, and the electronic circuitry (PCB 12, processor 16, etc) being located on an opposite side of the carrier 5. The carrier material is continuous, i.e. there are no through holes, at least not in the surfaces defining the receiver 10 and pocket 18.

Further, mounting the pressure sensor arrangement 17 on the carrier 5 provides the possibility of testing this functionality of the pen 1 before the pen 1 is finally assembled. Thus, the final assembly need not be made if defects are detected to the functionality of the pen 1.

It should also be appreciated that other types of sensors may be used to activate the pen 1 when the pen point 9 is pressed against a writing surface 14. For instance, part of an open electric circuit (not shown) may be arranged in the position of the pressure sensor 19. In this case, the insert 22 is provided with conductive pins or a conductive sheet which, as the pen point 9 is being pressed against the writing surface 14, contacts and closes the electric circuit. Alternatively, an optical or magnetic detector can be used to sense the motion of the ink cartridge 8. In WO 03/69547, a thorough description of a pressure sensor is given. The aspects of

the pressure sensor described in WO 03/69547 may also be used in connection with the present invention.

The pen 1 further comprises a vibrator 20, which is attached to a rear end wall of the carrier 5. The vibrator 20 is connected to control equipment on the printed circuit board 12. The vibrator 20 may vibrate for giving feedback to the user. Thus, for instance, when the pen 1 has detected that the user has ticked a checkbox, the vibrator 20 may vibrate for signalling to the user that the pen 1 has correctly detected that the checkbox was ticked. Further, when the pen 1 detects an error, the vibrator 20 may vibrate continuously. Such an error may be when the pen 1 does not recognize a pattern on the writing surface 14 which it expects to recognize or when any other error occurs in the pen 1.

The carrier 5 and the parts mounted on the carrier 5, such as the printed circuit board 12, the optical system 11, the pressure sensor arrangement 17, the vibrator 20, and the ink cartridge 8 form a modular unit for the pen 1. This modular unit can be tested for functionality and resistance to certain outer conditions without the need for final assembly of the pen 1. This provides that defective modular units may be discarded or corrected before final assembly of the pen 1. Further, the arrangement of all these parts in one modular unit provides the possibility that the modular unit is delivered by a subcontractor to a pen manufacturer or pen dealer. The pen manufacturer/dealer need then merely package the modular unit with a battery and any other desired or needed parts in an outer shell before marketing the pen 1. It may also be conceivable that the battery forms a part of the modular unit. In either case, the modular unit provides the basic functionality of the pen 1.

When a user writes with the activated pen 1, an area on the writing surface 14 adjacent or around the pen point 9 is irradiated by the irradiating system 13 of the

optical system 11. The imaging system 15 of the optical system 11 records images of an irradiated area of the writing surface 14 adjacent the pen point 9, and the processor 16 calculates the position of the pen 1 based on the images. Here, a specific pattern (not shown) on the writing surface 14 may be used, for instance of the type as described in WO 00/73983, WO 01/26033, WO 01/71653, WO 03/042912, US 5,477,012 and US 6,330,976. With the aid of the pattern on the writing surface 14, the position of the pen 1 can at any moment be determined, and in this way the user's writing can be recorded.

In order to achieve good image quality, the area imaged by the imaging system 15 needs to be properly irradiated by the irradiating system 13. This is achieved, as explained above, by the irradiating system 13 emitting radiation in a solid angle γ that covers a space formed by the possible positions of the imaged area dependent on e.g. the angles between the pen 1 and the writing surface 14 and the tolerances in the components of the pen 1.

Referring now to Figs 8-12, an analysis system will be described. The entire analysis system is shown in Fig. 8, whereas parts of the analysis system are shown in detail in Figs 9-12. The analysis system comprises the printed circuit board 12, on which the processor 16 is arranged and on which the optical system 11 is mounted. The analysis system may be used for irradiating an object and imaging the irradiated object. The recorded images may be analysed in the processor 16, which is connected to the imaging system 15 on the printed circuit board 12. Thus, the analysis system provides an analysis functionality, which may be used in differing optical analysis applications. The analysis system is particularly suitable for use in handheld devices, wherein an object is to be analysed using images of the irradiated object. The analysis system will below be

described in relation to the application of the analysis system in an electronic pen, but it should be emphasized that the scope of protection of the present application is in no way limited to this use of the analysis system. It may, for instance, be applied in a bar code reader instead.

The analysis may be achieved in each specific application by programming the processor 16 to perform image analysis. The image processor 16 may perform pre-processing of the images, whereas an external computer unit extracts information from the images and calculates coordinates on the writing surface 14. Preferably, the image processor 16 performs all processing on the information in the images. Alternatively, all or parts of the image processor 16 may be integrated in the radiation sensor 24. As a further alternative, the image processor 16 may be implemented as an application-specific integrated circuit.

The analysis performed is highly dependent on the application of the analysis system and the needed information from the recorded images. Therefore, in the following description, referring now to Figs 9-12, the optical system 11 of the analysis system will be described in detail, whereas the function of the processor 16 will be only briefly discussed.

The optical system 11 comprises an irradiating system 13 for irradiating the object to be analysed and an imaging system 15 for imaging the object. As shown in Fig. 8, the irradiating system 13 and the imaging system 15 are arranged adjacent to each other. Thus, the effect of varying angles between the pen point 9 and the writing surface 14 on the relationship between the irradiated area and the imaged area is kept low.

The optical system 11 may, as shown in Fig. 8, be mounted on the printed circuit board 12. This is a rigid and simple assembly of the optical system 11.

Referring now to Fig 9, the imaging system 15 will be schematically described. The imaging system 15 comprises a two-dimensional radiation sensor 24. The two-dimensional radiation sensor 24 may be an electrooptical image sensor, such as a CCD or a CMOS sensor. The radiation sensor 24 may be arranged in a package 25 that is soldered to the printed circuit board 12. Alternatively, a sensor chip may be attached directly to the printed circuit board 12, for example via wedge or ball bonding. The radiation sensor 24 is connected through the printed circuit board 12 to the image processor 16 for analysing the images.

The imaging system 15 further comprises a sensor boresight unit 26 for directing radiation onto the radiation sensor 24. In the embodiment of Fig. 9, the sensor boresight unit 26 is mounted on the printed circuit board 12 around the radiation sensor 24. The sensor boresight unit 26 has a sensor pocket 27 to receive the package 25 with the radiation sensor 24. Thus, all radiation that reaches the radiation sensor 24 needs to propagate through the sensor boresight unit 26. The sensor boresight unit 26 comprises a mirror 28, which is arranged above the radiation sensor 24. The mirror 28 is arranged to reflect radiation from the writing surface 14 onto the radiation sensor 24, to redirect the optical axis of the imaging system 15 accordingly. The mirror 28 should have a surface that is sufficiently large to reflect radiation that covers the active area of the radiation sensor. In order to account for tolerances due to assembly, the mirror 28 may have a larger surface than the active area of the radiation sensor 24. The mirror surface 24 need not be planar, but a slightly curved mirror surface 24 is also conceivable.

The redirection of radiation in the mirror 28 implies that the radiation sensor 24 may be mounted on the printed circuit board 12, which extends in a direction substantially perpendicular to the writing

surface 14. The radiation is redirected essentially 90° in the mirror 28, so that the optical axis of the imaging system 15 in the optical path in front of the mirror 28 is essentially parallel with the printed circuit board 12. Thus, the printed circuit board 12 will not obscure the view of the imaging system 15. The optical axis of the imaging system 13 in front of the mirror 28 may be somewhat inclined, typically by less than about 15°, preferably by less than about 10°, and most preferably by about 3°-8°, to the longitudinal axis of the ink cartridge 8 so that the imaging system 15 will view an area of the writing surface 14 close to the pen point 9.

The sensor boresight unit 26 further comprises a lens 29 in front of the mirror 28 in the optical path of the radiation. The lens 29 is arranged to focus radiation from the writing surface 14 onto the radiation sensor 24 via the mirror 28. The lens 29 is arranged in the sensor boresight unit 26 such that the distance between the lens 29 and the sensor 24 is shorter than the distance between the lens 29 and the writing surface 14, whereby the imaged area on the writing surface 14 is increased. The imaged area should be sufficiently reduced in size so that a sufficient area of the writing surface 14 is imaged on the radiation sensor 24 to determine the position of the pen point 9. The imaged area may, however, not be reduced to such a degree that the smallest required resolution of the image is imaged onto an area that is smaller than a pixel size in the radiation sensor 24.

The sensor boresight unit 26 also comprises an aperture stop 30. The aperture stop 30 reduces the amount of radiation passed towards the radiation sensor 24. If an opening of the aperture stop 30 is increased, more radiation is passed towards the radiation sensor 24, but the depth of field of the imaging system 15 is simultaneously decreased.

In one embodiment, shown in Fig. 10, the lens and the mirror are implemented in one optical component 31. The optical component 31 is a solid optics component denoted herein as an imaging prism. The imaging prism 31 may be produced of a plastics material, such as polymethylmethacrylate (PMMA), polycarbonate Zeonex®, polystyrene, nylon, or polysulfone. The imaging prism 31 has a base 32 to be attached to the printed circuit board 12, e.g. by gluing, snapping or ultrasonic welding. The sensor pocket 27 is arranged in the base 32. The surface inside the sensor pocket 27 of the imaging prism 31 may be planar or slightly curved and forms an exit surface 33 for radiation towards the radiation sensor 24. The imaging prism 31 further has a mirror surface 34 which is arranged above the sensor pocket 27 and inclined in relation to the base 32. The mirror surface 34 is metallized on the outside for providing a reflective surface. Thus, the radiation incident on the mirror surface 34 from within the imaging prism 31 will be reflected in the mirror surface 34. Alternatively, a glass mirror is glued to the imaging prism 31 by means of an optical glue. The imaging prism 31 also has an essentially tubular part 35 which extends from the mirror surface 34 and is at least partly supported by the base 32. A longitudinal axis of the tubular part 35 extending from the mirror surface 34, which axis also forms an optical axis of the imaging system 15, is slightly inclined towards a plane, in which the base 32 is located. This provides that the optical axis is tilted to the longitudinal axis of the ink cartridge 8, whereby the imaging system 15 may image an area close to the pen point 9. The end of the tubular part 35 farthest away from the mirror surface 34 extends beyond the base 32. This end forms an entrance surface 36 of the imaging prism 31. The entrance surface 36 is curved to form the lens and is arranged to receive radiation from the object plane.

All surfaces of the imaging prism 31 except the entrance surface 36 and the exit surface 33, and optionally the mirror surface 34, may be covered with a radiation-transfer material. The radiation-transfer material has an index of refraction that is sufficiently matched to the index of refraction of the imaging prism material, such that the major part of any radiation impinging on these covered surfaces is transmitted into the radiation-transfer material instead of being reflected back into the imaging prism. The radiation-transfer material may also be selected to absorb the relevant wavelengths, typically with an absorbance of at least 0.5, to prevent the transferred radiation from spreading within the pen. The provision of a radiation-transfer material on the outside of the imaging prism prevents stray radiation from reaching the radiation sensor. Since an effective prevention of internal reflections in the imaging prism is provided, the surfaces of the imaging prism may be arranged close to the desired optical path in the imaging prism. Thus, the imaging prism may have a small size. The radiation-transfer material may also be selected to prevent radiation from entering the imaging prism through other surfaces than the entrance surface. In one preferred embodiment, the radiation-transfer material is a black paint.

Further, there is provided a notch 37 in the base 32. This notch 37 forms a barrier in front of the radiation sensor 24 as seen from the entrance surface 36 and provides that radiation is not allowed to impinge on the radiation sensor 24 directly from the entrance surface 36 without interacting with the mirror surface 34.

In this embodiment, the sensor boresight unit 26 consists of the imaging prism 31 and an aperture stop 38. The aperture stop 38 may be implemented as a cap to be mounted over the tubular part 35 of the imaging prism 31

at the entrance surface 36. The aperture stop 38 has an opening 39 to be arranged in front of the entrance surface 36 to allow radiation into the prism 31. The aperture stop 38 may be formed in plastics material and be glued or snapped onto the prism 31. The aperture stop 38 may alternatively be provided by masking a part of the entrance surface 36 that should not transmit radiation, e.g. with the radiation-transfer material used for the other surfaces of the imaging prism 31.

In another embodiment, shown in Fig. 11, the sensor boresight unit 26 is implemented as a housing 40 containing the needed optical components. Radiation is propagated through the housing 40 in a channel 41 formed in the housing 40. The housing 40 has essentially the same shape as the imaging prism 31 and thus a similar optical path is formed within the housing 40. A base 42 of the housing 40 may have a large surface towards the printed circuit board 12. Further, the housing 40 may be formed in a material optimal for strongly attaching the housing 40 to the printed circuit board 12 by e.g. gluing. The housing 40 has an opening 43 in the base 42 forming the sensor pocket, which is open into the channel 41.

A mirror 44 is attached by e.g. gluing covering an opening in the housing 40 above the opening 43 in the base 42. The housing 40 may provide slots for receiving the mirror 44 and defining the position of the mirror 44. The housing 40 further provides a tubular part 45 of the channel 41 extending from the mirror 44. The housing 40 may have a thick base wall which forms the lower inside surface of the channel 41. At an end of the tubular part 45, inside walls of the housing 40 may have radial protrusions 46 for reducing the diameter of the channel 41 and effectively forming an aperture stop 47. The aperture stop 47 may be arranged a short portion into the channel 41 of the housing 40. The housing 40 further comprises an outer opening for receiving radiation from

the writing surface 14. A lens 48 may be attached in the housing 40 in front of the aperture stop 47, for example by means of gluing, crush ribs, ultrasonic welding, form fitting, snap fitting, etc.

The aperture stop may alternatively be arranged as a separate component, which is inserted into and attached to the housing 40. The aperture stop may as a further alternative be provided by means of a cap that is arranged over the front end of the housing 40. Such a cap may also include the lens 48.

The housing 40 may be formed in a radiation-absorbing material for absorbing stray radiation. The inner surface of the housing 40 may also or alternatively be coated with a radiation-absorbing material. The inner surface of the housing 40 may be roughed or textured to reduce specular reflections. Alternatively or additionally, the inner surface of the housing 40 may have one or more surfaces that directs specular reflections away from the opening 43. The inside walls of the protrusions 46 forming the aperture stop 47, i.e. the walls closest to the mirror 44, may be tapered such that the protrusion 46 is thicker closer to the wall of the housing 40. Thus, reflections in these protrusion walls are steered into the walls of the housing 40. These protrusion walls may also be roughed or textured.

When decoding a position-coding pattern on the writing surface 14, the distance D is important to relate the position of the pen stroke to the physical pen stroke on the writing surface 14. For instance, the processor 16 can be arranged to calculate, based on one image, the spatial orientation of the pen 1 and a position, and, knowing the position, the spatial orientation and the distance D, to calculate a writing position, i.e. the position of the contact point P. Deviations from the nominal value of the distance D thus introduce systematic errors in the calculated writing positions.

The imaging system 15 is, however, preferably arranged to image an area of the writing surface 14 that is partly obscured by a tip of the ink cartridge 8. The tip consists of a ball held by a cone leading up to the cylindrical body of the ink cartridge 8. The edge between the cone and the cylindrical body of the ink cartridge 8 may then form an obscuration edge in the recorded images, although any other part of the tip may form the obscuration edge. The obscuration edge may be nominally placed in the image such that the tolerance chain of components of the pen 1 keeps the obscuration edge placed within the image. Thus, the obscuration edge may always be detectable in the images. This implies that the position of the obscuration edge in the recorded images could be used for calibrating the distance D for individual pens. It should be noted that the distance D is a vector in the reference plane and the calibration is therefore made in two dimensions.

The position-coding pattern on the writing surface 14 is suitably printed to be visible in the near infrared wavelength band. Further, the ink from the pen 1 may be chosen in order not to be visible in the near infrared wavelength band such that it will not interfere with the information of the position-coding pattern. In order not to image wavelengths in the visible region, an infrared filter 49 (Fig. 4) may be arranged in front of the lens 29 of the imaging system 15. The infrared filter 49 may absorb all wavelengths shorter than the near infrared wavelengths. The infrared filter 49 will then absorb undesired radiation from sunlight and external illumination.

The function of an infrared filter may be implemented anywhere in the imaging system 15. Thus, the infrared filter may alternatively be arranged in the housing 40 or be integrated in the imaging prism 31 by the material of the imaging prism 31 being highly absorptive to wavelengths shorter than the near infrared

wavelengths. By placing the infrared filter 49 in front of the lens 29 of the imaging system 15, the infrared filter 49 may also serve as a protective window.

Referring now to Fig. 12, the irradiating system 13 comprises a radiation source 50, which is arranged to emit radiation. The source 50 is typically a light-emitting diode (LED) or a laser diode that emits radiation in a limited wavelength band. The source 50 may be mounted in a through hole 51 on the printed circuit board 12 and be electrically connected thereto. The irradiating system 13 further comprises a radiation guide 52 for directing the radiation to the desired area on the writing surface 14. The radiation guide 52 may be formed in one piece of a plastic material, such as PMMA, polycarbonate, Zeonex®, polystyrene, nylon, or polysulfone.

The radiation guide 52 is mounted to the printed circuit board 12 over the through hole 51. The radiation guide 52 comprises a base surface 53 which may be attached to the printed circuit board 12 by e.g. gluing. The base surface 53 may comprise a flange 54 for providing a larger attachment area to the printed circuit board 12. The flange 54 is arranged merely for securing attachment of the radiation guide 52 and not for transmitting radiation from the source 50. The flange 54 ensures secure attachment of the radiation guide 52 such that the radiation guide 52 will not part from the printed circuit board 12 if the pen is exposed to a mechanical shock. The radiation guide 52 may further comprise guidance pins or holes (not shown) for controlling the positioning of the radiation guide 52 in relation to the printed circuit board 12 and/or the adjacent sensor boresight unit 26 of the imaging system 15.

The radiation guide 52 comprises a source receiving pocket 55, which is to be arranged over the through hole 51 in the printed circuit board 12. The pocket 55 has a

planar entrance surface 56 at its base and radiation from the source 50 enters the radiation guide 52 through this entrance surface 56.

The radiation guide 52 further has a mirror surface 57 which is arranged above the source receiving pocket 55 and inclined in relation to the base surface 53. The mirror surface 57 is metallized on the outside to provide a reflective surface. The radiation is redirected essentially 90° in the mirror surface 57, so that the optical axis of the irradiating system 13 in the optical path after the mirror surface 57 is essentially parallel with the printed circuit board 12. Thus, the printed circuit board 12 will not obscure the irradiating of the writing surface 14 by means of the irradiating system 13. The optical axis of the irradiating system 13 after the mirror surface 57 may be somewhat inclined, typically by less than about 15°, and preferably by less than about 10°, to the longitudinal axis of the ink cartridge 8 so that the irradiating system 13 will irradiate an area of the writing surface 14 close to the pen point 9.

The radiation guide 52 forms an essentially tubular shape for guiding the radiation after it has been reflected by the mirror surface 57. The radiation exits the radiation guide 52 through an exit surface 58, which is provided at an end of the tubular shape. All surfaces except the entrance surface 56 and the exit surface 58 may be metallized, whereby radiation is controlled to exit only through the exit surface 58. Radiation impinging on other walls will thus be reflected back into the radiation guide 52.

The tubular shape of the radiation guide 52 has an essentially constant cross-section. By varying the cross-section of the tubular shape, the shape of the irradiated area may be changed. Further, the longer the tubular shape is, the more uniform the emitted radiation of the radiation guide 52 will be. However, it may be sufficient to keep the tubular shape so short that most of the

emitted radiation will only have been reflected once before exiting the radiation guide 52. The minimum width of the cross-section of the tubular shape in a direction parallel to the printed circuit board surface is mainly determined by the size of the source receiving pocket 55. The cross-section of the tubular shape should be kept as small as possible to keep the radial size of the pen 1 down, while the emitted radiation should irradiate a sufficiently large area. To this end, the tubular shape of the radiation guide may be designed with an asymmetrical cross-section.

As illustrated in Fig. 11, the exit surface 58 of the radiation guide 52 is angled to a longitudinal axis of the tubular shape of the radiation guide 52 so that the radiation is redirected in the exit surface 58 towards the writing surface 14 to be irradiated. The redirection of radiation in the exit surface 58 implies that an optical axis of the irradiating system 13 beyond the radiation guide 52 converges with the optical axis of the imaging system 15 towards the writing surface 14. The redirection of the optical axis of the irradiating system 13 in the exit surface 58 is needed, since the optical axis of the irradiating system 13 in the tubular shape of the radiation guide 52 is essentially parallel to the optical axis of the imaging system 15 in the tubular part 35 of the imaging prism 31 or in the channel 41 of the housing 40.

The exit surface 58 of the radiation guide 52 may be planar. Alternatively, the exit surface 58 may be curved to provide a surface power for controlling the size of the irradiated area.

Since the source 50 and the radiation sensor 24 are arranged close to each other on the printed circuit board 12, there is a need for preventing leakage of radiation directly from the source 50 to the radiation sensor 24. Some features of the optical system 11 mentioned above serve to hinder such leakage. Thus, the radiation guide

52 of the irradiating system 13 is metallized for preventing radiation to escape from other surfaces than the exit surface 58. Further, the imaging prism 31 or the housing 40 may be painted or coated by a non-transmitting material to prevent radiation from entering the imaging prism 31 or housing 40 through other surfaces than the entrance surface.

Further, the irradiation and imaging is performed in the near infrared wavelength band. If the printed circuit board 12 is essentially transparent in this wavelength band, then it is important to ensure that radiation is not transmitted through the printed circuit board 12 from the source 50 to the radiation sensor 24. This may be especially important, since the radiation sensor 24 may be transparent from its backside and may thus detect radiation that enters from beneath the radiation sensor 24. Thus, the through hole 51 in the printed circuit board 12 may be metallized to minimize direct leakage of radiation from the source 50 into the printed circuit board 12. Further, one or more layers of copper may be arranged in the printed circuit board 12 to reduce radiation propagation in the printed circuit board. Further, a non-transmitting glue may be used in attaching the imaging prism 31 or the housing 41 to the printed circuit board 12. Thereby, radiation is prevented from propagating in the interface between the imaging prism 31 or the housing 40 and the printed circuit board 12.

Moreover, where the window 49 is arranged in front of the lens 29 of the imaging system, there is a risk of reflections in the window 49 of the emitted radiation from the radiation guide 52 being directed into the entrance surface of the imaging system 15. The imaging system 15 should be arranged to receive radiation that has passed the window 49 through an area of the window 49 that does not coincide with the area of the window 49 that is irradiated by the irradiating system 13. However, to further reduce risks of detecting radiation that is

reflected in the window 49, the window 49 may be anti-reflection coated on one or both surfaces. Further, the window 49 may be angled such that reflections from the emitted radiation are deflected away from the imaging system 15.

It should be emphasized that the preferred embodiments described herein are in no way limiting and that many alternative embodiments are possible within the scope of protection defined by the appended claims.

For instance, the above writing means can be, instead of an ink cartridge, a fountain pen unit, a pencil unit, a felt pen unit, a magnetic head for cooperation with a selectively magnetisable base, a heating head for cooperation with a heat sensitive base, an electronically controlled ink jet unit, a miniaturized laser printer unit etc. It may even be conceivable that the writing means will not leave any trace of its path along the writing surface 14, and the writing that is detected by the imaging system and the image processor will not be visible to the eye. In this case, the writing means may be e.g. a stylus or a pointed bar or rod.

Further, in the above description, a lens is described in several different occasions. In such cases, the lens may be implemented as a single optics component exhibiting a lens function or alternatively as a lens package.

Likewise, the above-mentioned printed circuit board (PCB) is intended to encompass other equivalent structures, such as thick film hybrids of metal or ceramic material.

In an alternative embodiment, the sensor boresight unit is supported by the PCB without being directly attached thereto. More specifically, the PCB with the radiation sensor rests on one side of the carrier, with at least one through hole of the PCB being aligned with a corresponding receiving bore in the carrier. The boresight unit, which has at least one protruding guiding

pin, is mounted onto the PCB with the guiding pin being snugly fit into the through hole and the receiving bore, to thereby adequately line up the boresight unit, the radiation sensor, and the carrier. As an alternative or addition, there may be provided at least one corresponding guiding pin on the carrier for cooperation with a receiving bore on the boresight unit, via a through hole in the PCB. Further, the base of the boresight unit has at least one control surface for abutment on at least one corresponding control surface on the PCB and/or the radiation sensor. As mounted, the boresight unit is pressed against the PCB, to thereby minimize any variations in the position of the boresight unit in the normal direction of the radiation sensor. The boresight unit may be fixed to the carrier by means of external clamping fixtures and/or by means of welding, gluing, form fitting, press fitting, snap fitting, etc, for example via the guiding pins. Alternatively, similar means may be used to fix the boresight unit to the PCB, and to fix the PCB to the carrier.

In yet another alternative embodiment, the boresight unit is arranged to be supported directly by the carrier instead of by the PCB. Thus, the carrier comprises means for supporting the boresight unit, as well as means for supporting the PCB. These means may be implemented as cooperating pins and bores, form fits, snap fits, welding surfaces, gluing surfaces, etc.

In all of the above embodiments, the radiation source of the irradiating system may be mounted in any position directly on the carrier, on the PCB or on another component of the modular unit. However, the radiation source should preferably be kept in a close relationship to the imaging system, so as to minimize the effects of the pen orientation on the interrelationship between the imaged and irradiated areas on the writing surface. In one example, the radiation source is mounted in a holder on an outer surface of the sensor boresight

unit, which in turn is supported by the PCB. Thus, a short tolerance chain and, consequently, a well-defined relationship is obtained between the irradiating system and the imaging system. Further, by attaching the radiation source to the boresight unit, the radiation source may be brought closer to the object plane of the imaging system so that the radiation guide may be omitted. Also, by combining the optical system and the PCB with the carrier, the above advantages obtained in enabling a test of a modular unit before final assembly of an electronic pen are maintained.

CLAIMS

1. An optical system, comprising:

an irradiating system which has an optical axis within said irradiating system and includes a radiation source, and

an imaging system which has an optical axis within said imaging system and includes a two-dimensional radiation sensor, said imaging system being arranged to provide an image of an object being irradiated by said irradiating system,

wherein said radiation source and said two-dimensional radiation sensor are mounted on a common substrate,

c h a r a c t e r i z e d in that said optical axis of the irradiating system and said optical axis of the imaging system are non-coinciding within said systems.

2. The optical system according to claim 1, wherein the irradiating system is arranged to redirect radiation from the radiation source, and the imaging system is arranged to redirect radiation from the irradiated object towards the radiation detector.

3. The optical system according to claim 1 or 2, wherein the optical axis within the irradiating system and the optical axis within the imaging system run essentially in parallel to each other.

4. The optical system according to claim 3, wherein the optical axis within the irradiating system and the optical axis within the imaging system run essentially in parallel to the common substrate.

5. The optical system according to claim 4, wherein the optical axis within the irradiating system and the optical axis within the imaging system define a plane which is essentially parallel to and at a distance from the common substrate.

6. The optical system according to any one of the preceding claims, wherein the irradiating system further

comprises a radiation guide for guiding radiation from the radiation source towards the object.

7. The optical system according to claim 6, wherein the radiation guide presents non-exit surfaces at least part of which may be metallized.

8. The optical system according to claim 6 or 7, wherein the radiation guide presents an inclined radiation-redirecting exit surface.

9. The optical system according to any one of claims 6-8, wherein the radiation guide is mounted on the common substrate.

10. The optical system according to any one of the preceding claims, wherein the imaging system further comprises a sensor boresight unit for controlling a spatial origin of radiation transmitted towards the radiation sensor.

11. The optical system according to claim 10, wherein the sensor boresight unit is mounted on the common substrate.

12. The optical system according to claim 10 or 11, wherein the sensor boresight unit comprises a mirror for redirecting radiation from the object towards the radiation sensor.

13. The optical system according to any one of claims 10-12, wherein the sensor boresight unit comprises a lens for creating an image of adequate image quality on an image plane of the radiation sensor.

14. The optical system according to claim 10 or 11, wherein the sensor boresight unit comprises an optical component, which is arranged to transmit radiation towards the radiation sensor, and wherein the optical component comprises a mirror for redirecting radiation from the object towards the radiation sensor, and a lens for creating an image of adequate image quality on an image plane of the radiation sensor.

15. The optical system according to claim 14, wherein the sensor boresight unit further comprises an

aperture stop, which is arranged in front of the optical component.

16. The optical system according to claim 14 or 15, wherein the optical component presents outer surfaces at least part of which are covered with a material arranged to reduce internal reflections in said outer surfaces.

17. The optical system according to claim 10 or 11, wherein the sensor boresight unit comprises a housing, providing an internal channel, which is arranged to transmit radiation towards the radiation sensor, wherein a mirror for redirecting radiation from the object towards the radiation sensor and a lens for creating an image of adequate image quality on an image plane of the radiation sensor are mounted in the housing.

18. The optical system according to claim 17, wherein the guide unit further comprises an aperture stop arranged in said housing.

19. The optical system according to claim 17 or 18, wherein the housing presents inside surfaces at least part of which are arranged to reduce specular reflection of radiation.

20. An analysis system, comprising an optical system according to any one of the preceding claims, a printed circuit board implementing said common substrate, and an image processor for analysing image information received from the radiation sensor, wherein the optical system is supported by and the image processor is mounted on said printed circuit board.

21. A modular unit for an electronic pen having a writing means, said modular unit comprising a carrier, and an analysis system according to claim 20 being mounted on the carrier, said carrier having means for receiving said writing means in order to position the writing means in relation to the analysis system within the electronic pen.

22. The modular unit according to claim 21, wherein the modular unit has a dimension allowing the modular unit to be mounted inside the electronic pen.

23. The modular unit according to claim 21 or 22, wherein the printed circuit board of the analysis system is mounted on the carrier for mounting the analysis system on the carrier.

24. The modular unit according to any one of claims 21-23, wherein the carrier has an elongate shape which extends, when the modular unit is comprised in an electronic pen, in a longitudinal direction of the electronic pen.

25. The modular unit according to any one of claims 21-24, further comprising a pressure sensor which is mounted on the carrier.

26. The modular unit according to any one of claims 21-25, further comprising means for forming attachment to an outer shell part of the electronic pen.

27. The modular unit according to any one of claims 21-26, further comprising a vibrator unit which is mounted on the carrier.

28. The modular unit according to any one of claims 21-27, further comprising a wavelength filter mounted on the carrier.

29. A sensor boresight unit for transmitting radiation from an object to a radiation sensor, said sensor boresight unit comprising:

a housing, which provides an internal channel that changes direction at a turn within said housing and further provides a radiation entrance end and a radiation exit end of said channel,

a lens, which is mounted in the internal channel at said radiation entrance end of said housing, and

a mirror, which is mounted in the housing at said turn of the internal channel for redirecting radiation along the change of direction of the internal channel.

30. An optical component for transmitting radiation from an object to a radiation sensor, said optical component being formed by a solid body defining a radiation path within the body, said solid body comprising:

a radiation entrance surface for receiving radiation into said radiation path, said entrance surface being curved for forming a lens,

a radiation exit surface,

a tubular part for transmitting radiation in the radiation path along a longitudinal axis of the tubular part, and

a mirror surface at an end of the tubular part opposite the entrance surface, wherein a normal of the mirror surface is slanted to the longitudinal axis of the tubular part such that the radiation path is redirected in the mirror surface towards the radiation exit surface of the solid body.

31. A modular unit for an electronic pen having a writing means, said modular unit comprising:

a carrier,

a printed circuit board, which is mounted on the carrier, and

an optical system, which is mounted on the carrier, said optical system comprising an irradiating system including a radiation source and an imaging system including a two-dimensional radiation sensor, the imaging system being arranged to provide an image of an object irradiated by said irradiating system,

wherein said carrier has means for receiving said writing means in order to position the writing means in relation to the optical system within the electronic pen.

32. The modular unit according to claim 31, wherein the imaging system comprises a sensor boresight unit for controlling a spatial origin of radiation transmitted towards the radiation sensor.

33. The modular unit according to claim 32, wherein the sensor boresight unit is supported by the printed circuit board.

34. The modular unit according to claims 32 or 33, wherein the radiation source of the irradiating system is carried by the sensor boresight unit of the imaging system.

ABSTRACT

An optical system is arranged to irradiate an object and to transmit an image of the object to an image plane. The optical system comprises an irradiating system comprising a radiation source, and an imaging system comprising a two-dimensional radiation detector. The radiation source and said radiation detector are arranged in such relationship to each other as to be mountable on a mutual substrate. An optical axis in the components of the irradiating system is separate from an optical axis in the components of the imaging system.

The optical system may be arranged as a part of an analysis system and further as a part of a modular unit for an electronic pen.

Elected for publication: Fig. 2

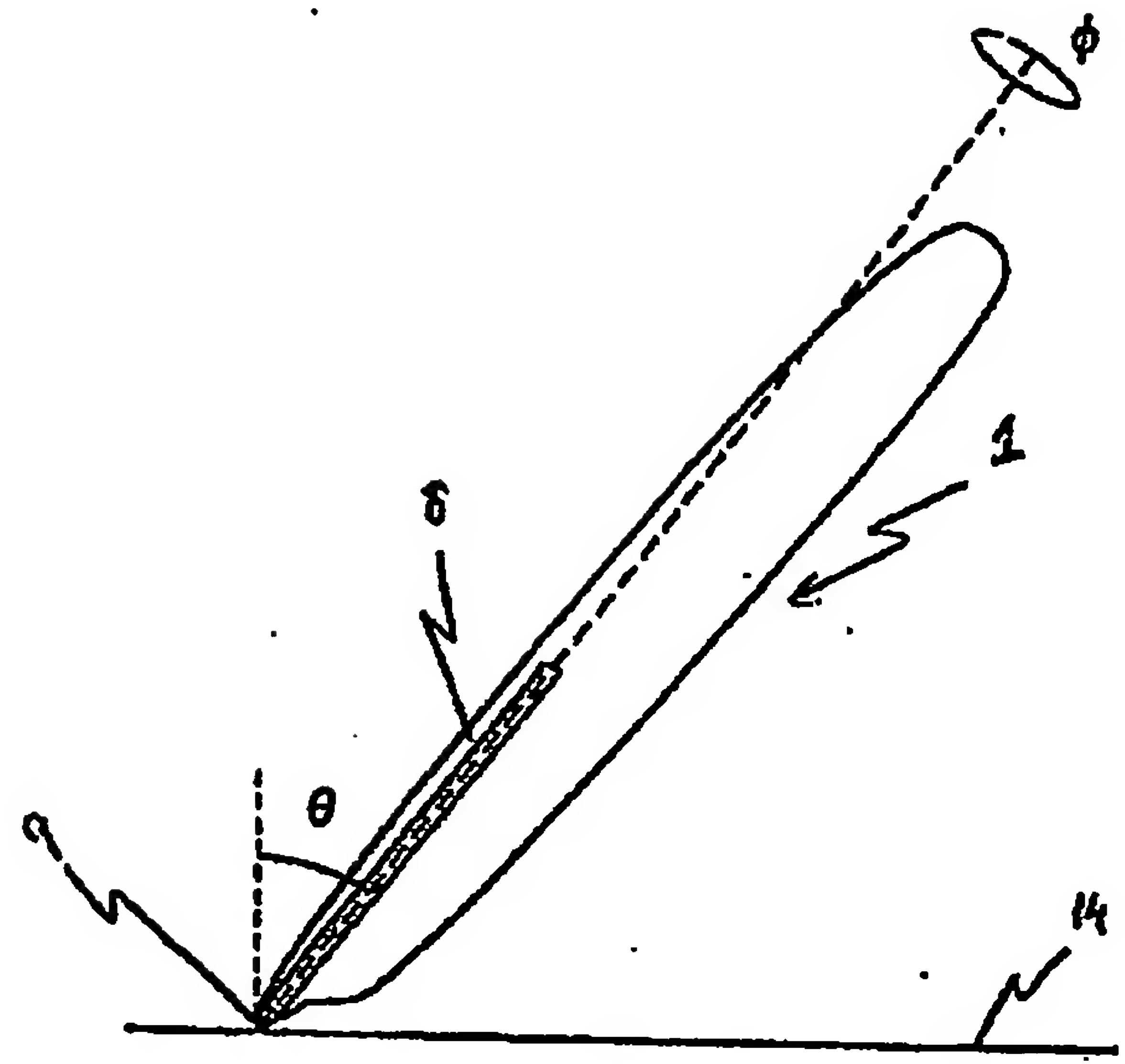

Fig 1a

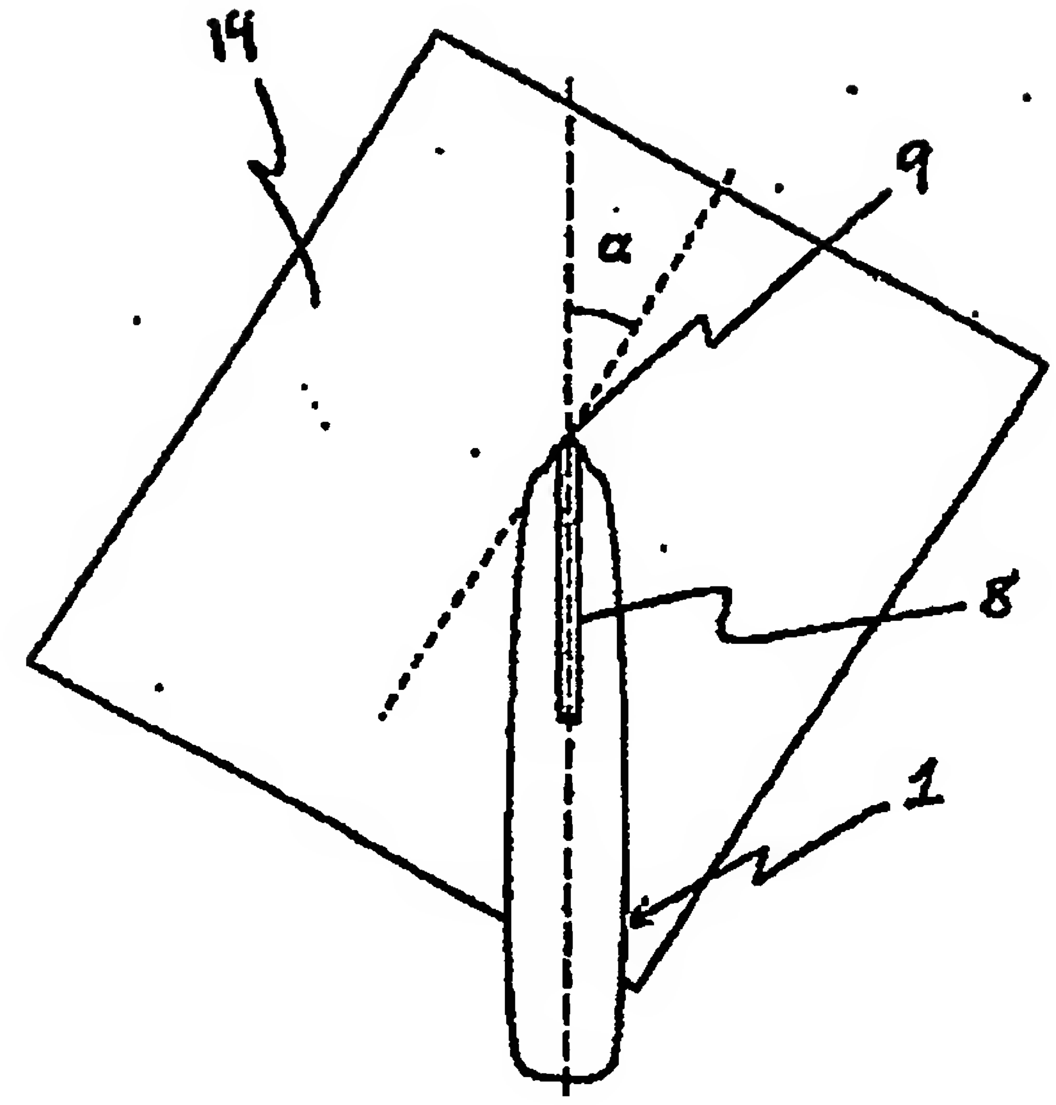

Fig 1b

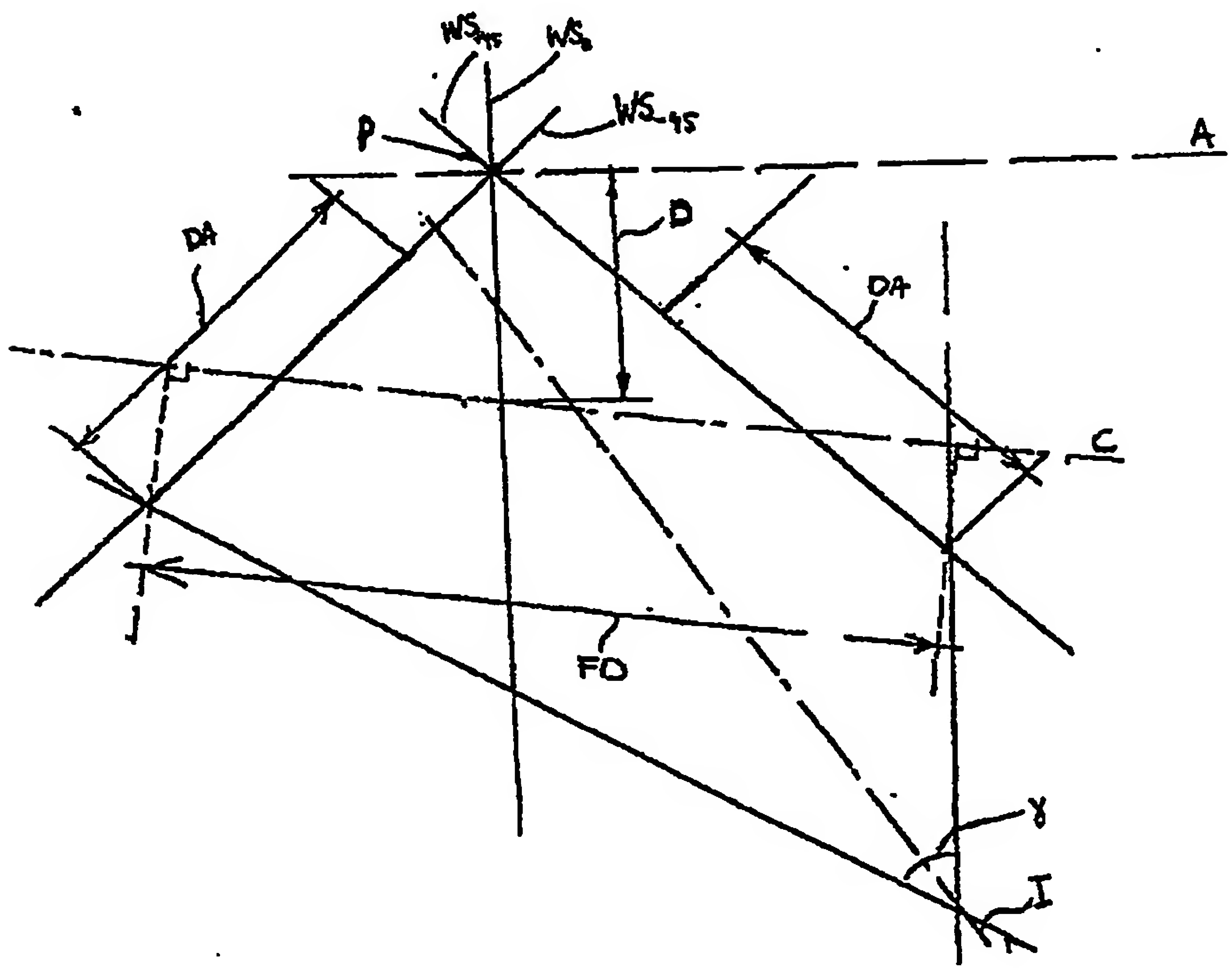

Fig 2

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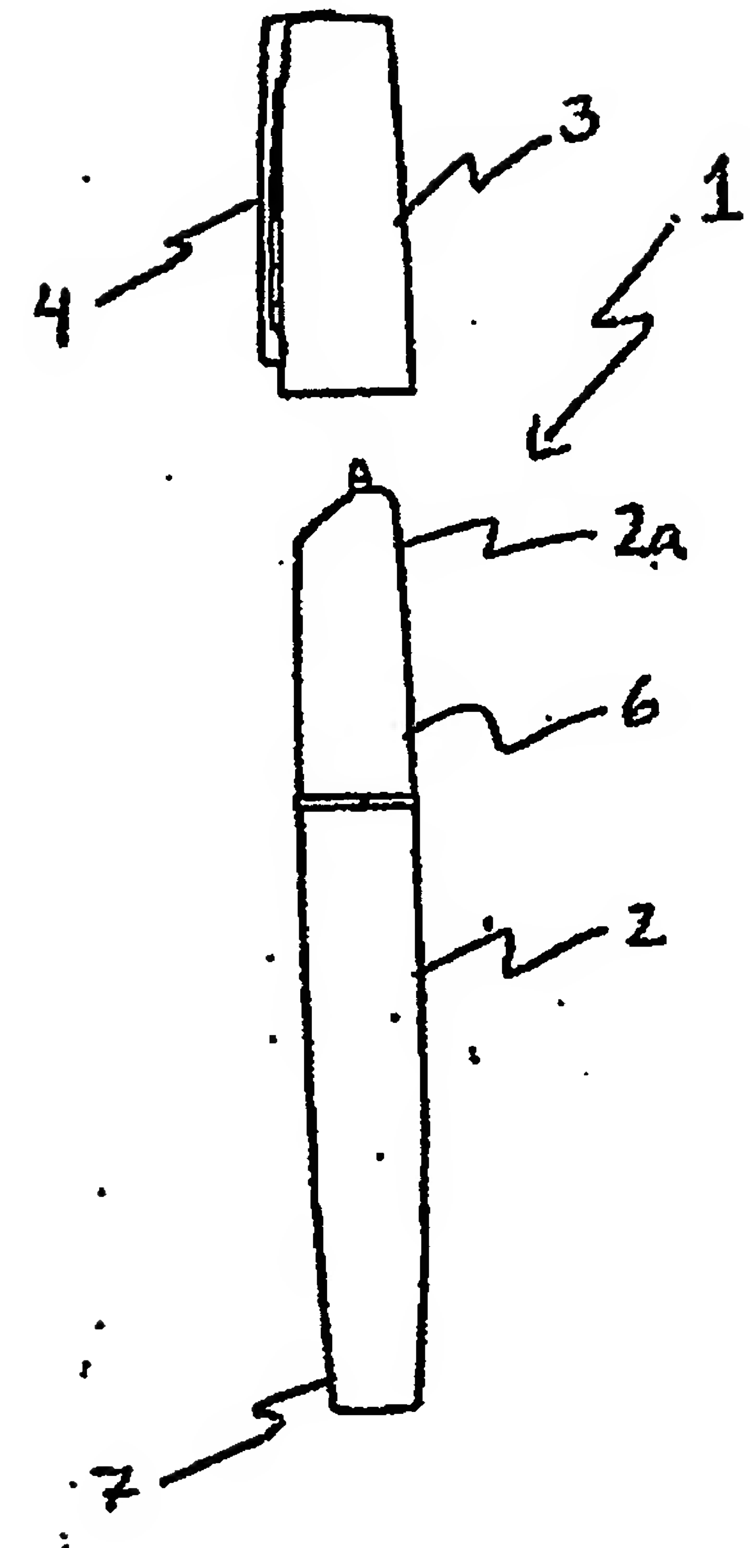

Fig 3

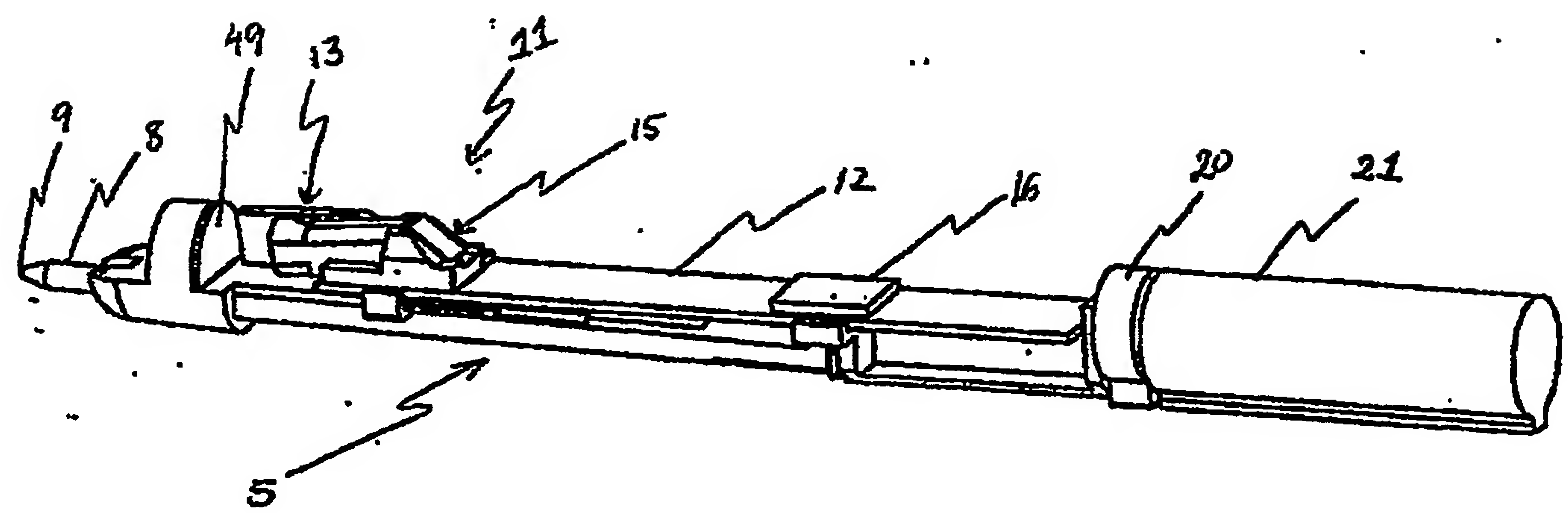

Fig 4

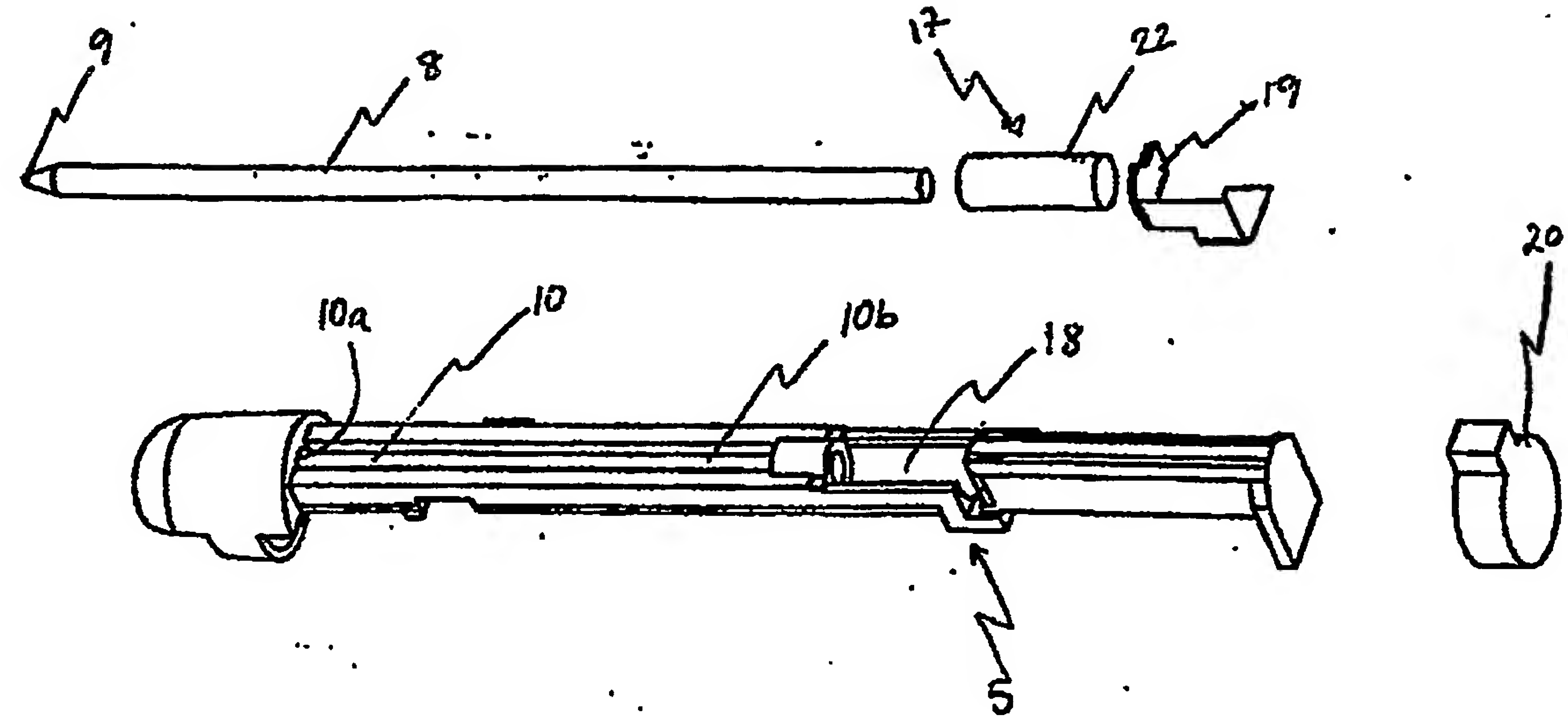

Fig 5

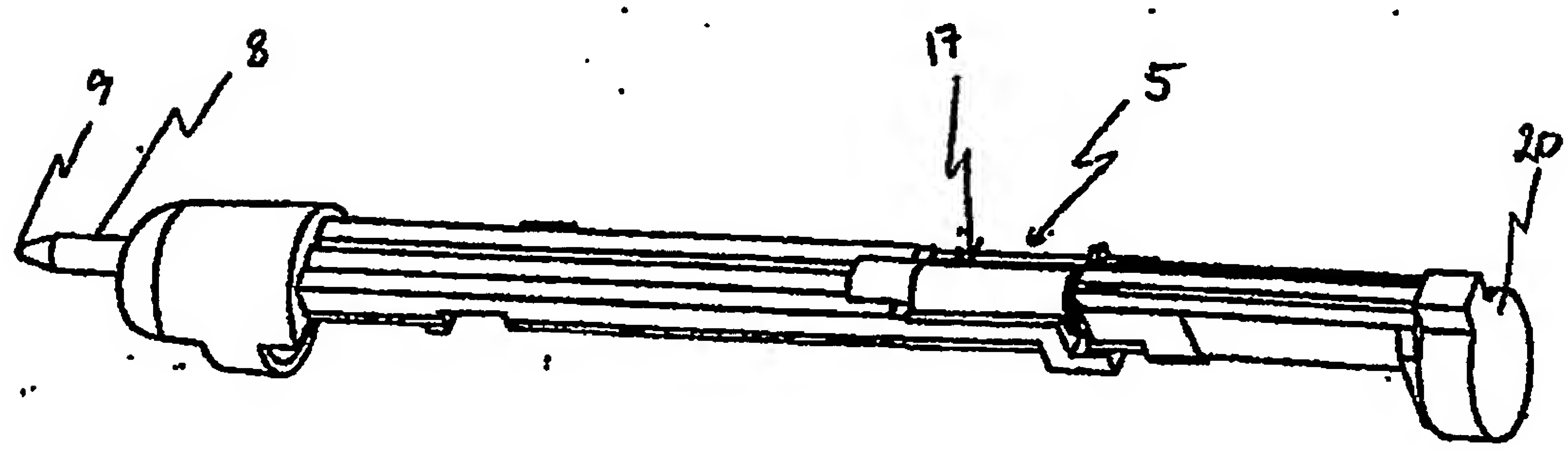

Fig 6

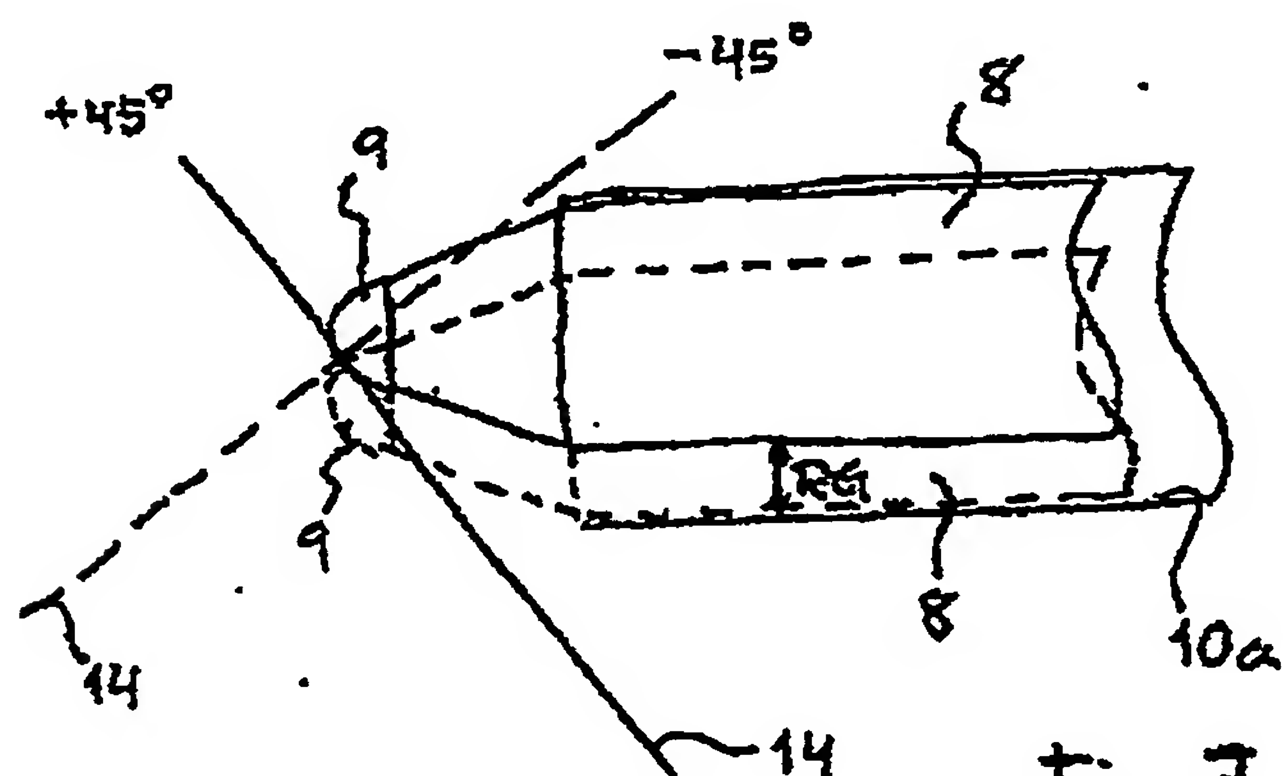

Fig 7

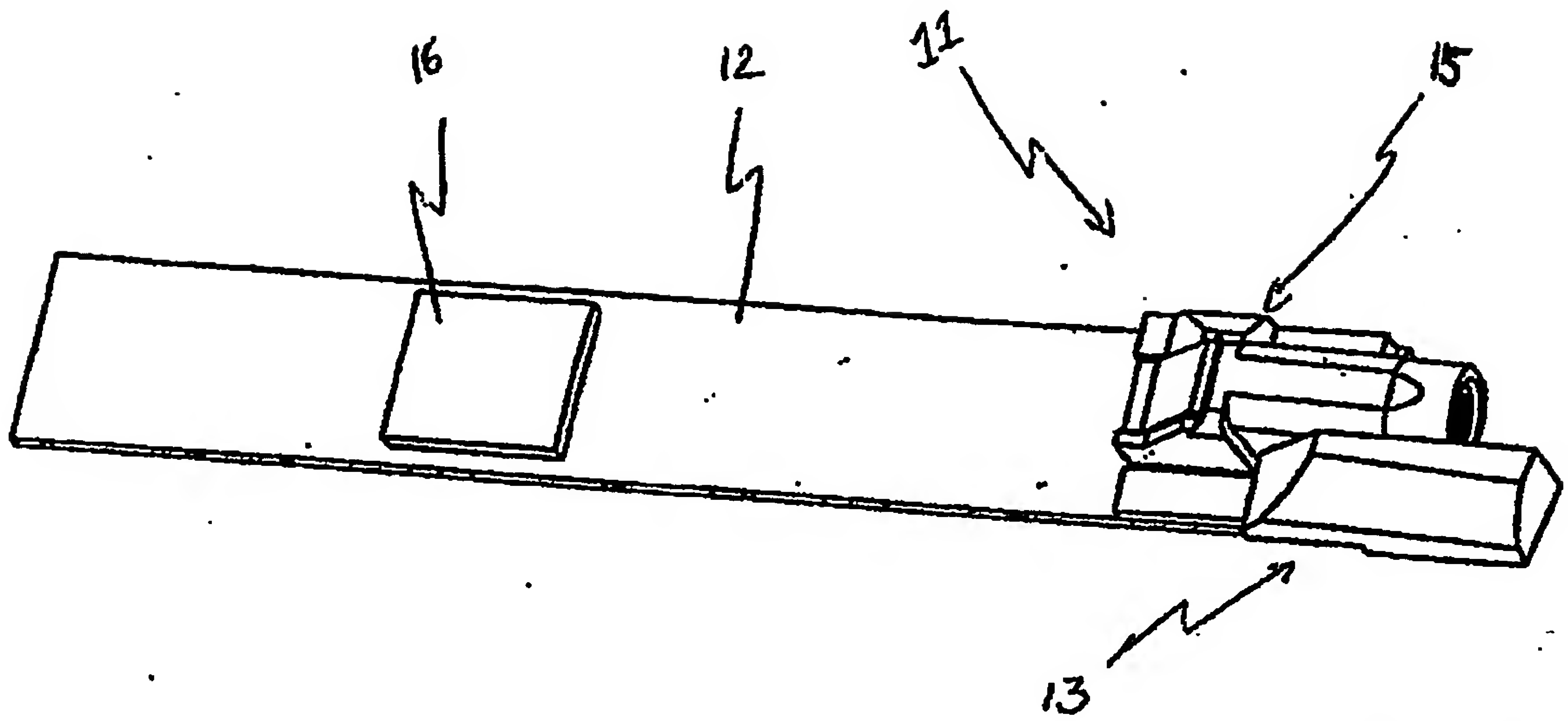

Fig 8

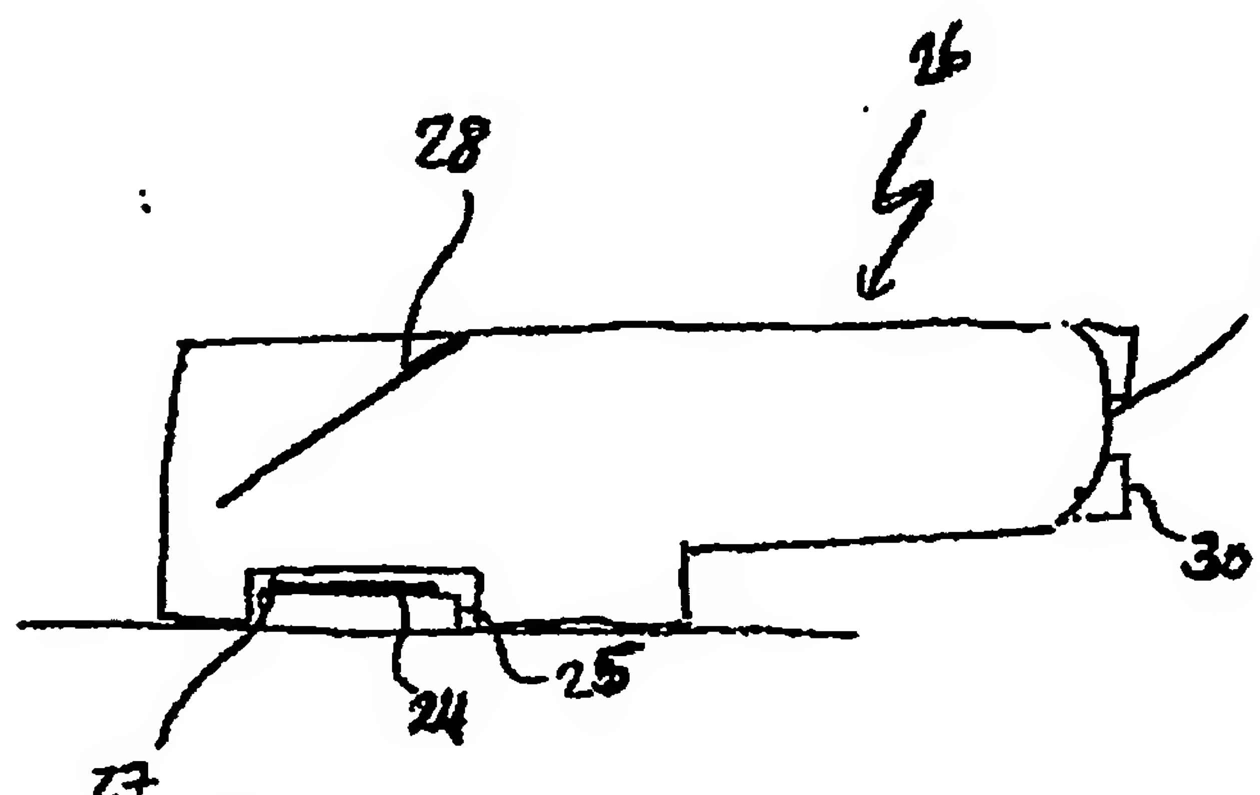

Fig 9

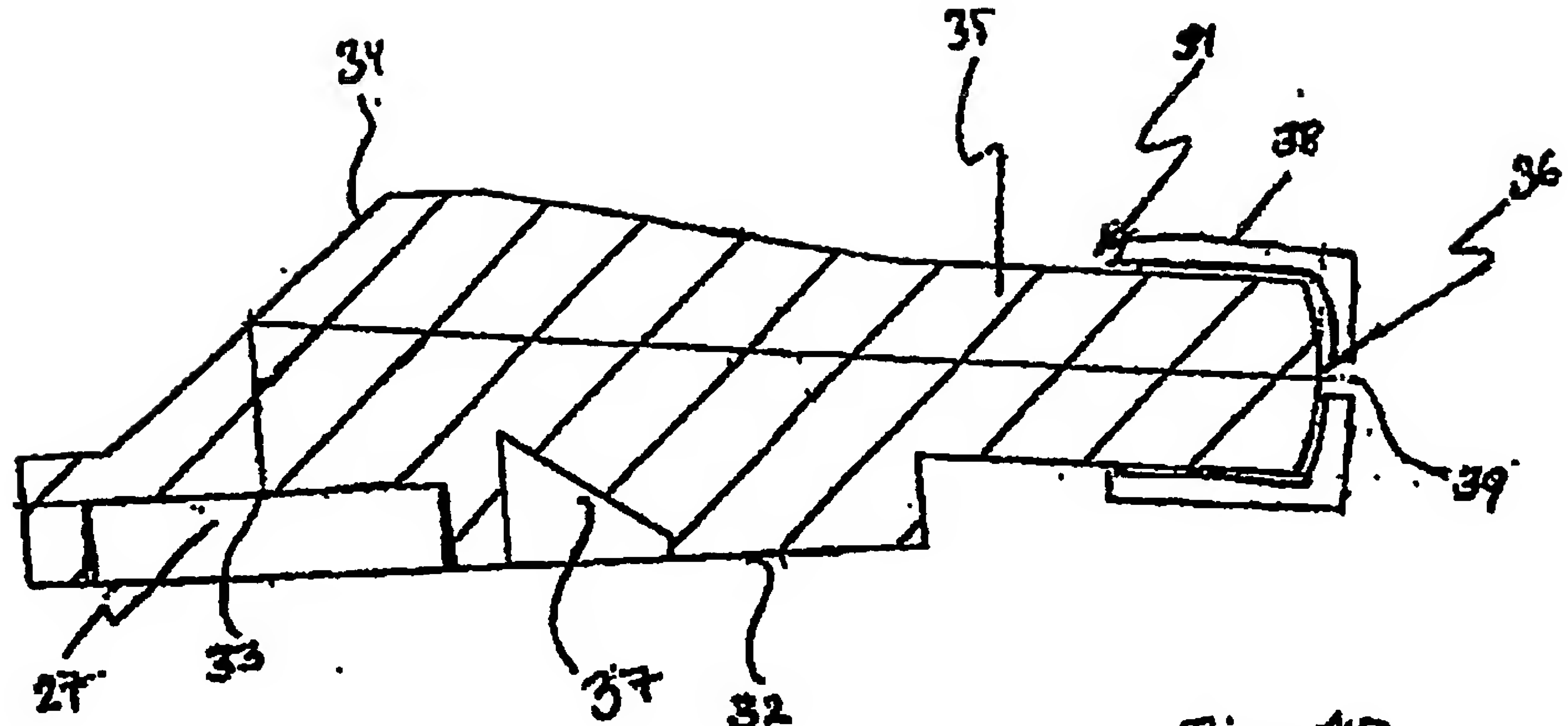

Fig 10

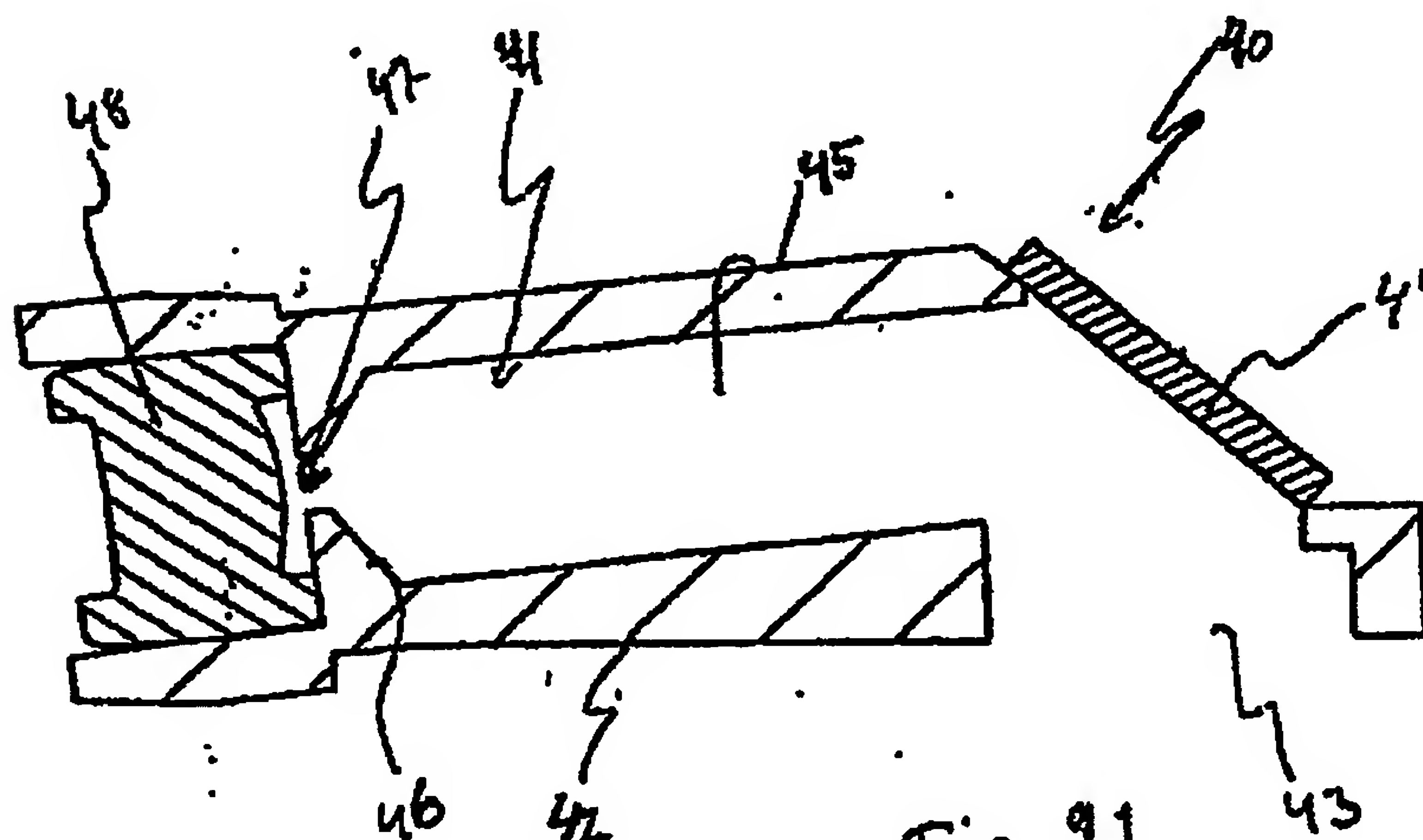

Fig 11

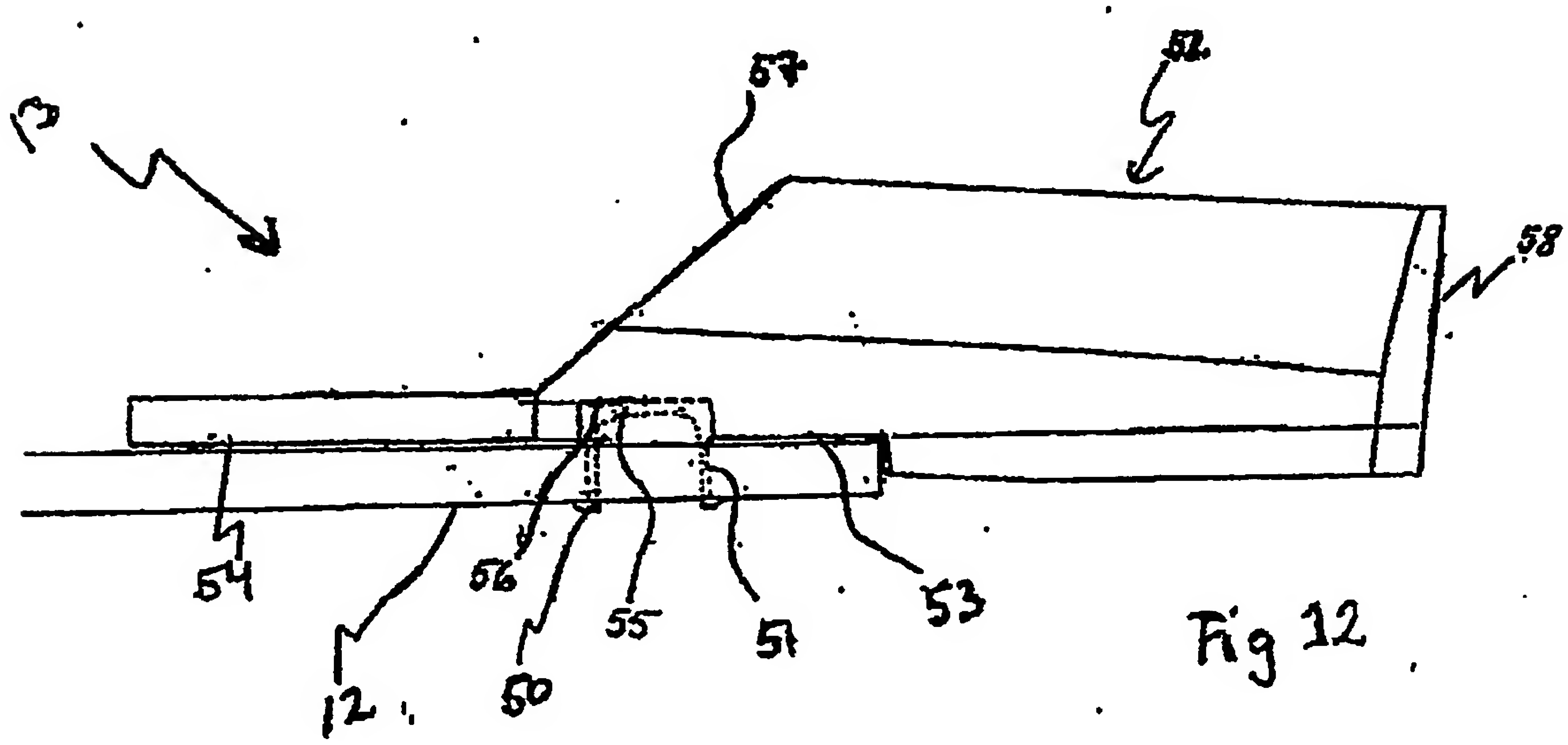

Fig 12

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